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Road and Rail Infrastructure III

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URBAN PAVEMENT SURFACES HEATING – INFLUENCING PARAMETERS

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Abstract

Urban heat islands are among most serious environmental problems in cities because overheating of the pavement surfaces during summer season causes discomfort for citizens and increased consumption of energy. The strategies for solving this problem are different but using materials which have favorable thermal characteristics is emphasized as important part of those strategies. Understanding of parameters that affect and contribute to the urban heat island and more precisely to the increased heating of the urban pavement surfaces is necessary in that process to assure that future reconstructions and constructions in urban areas are done in the best possible way.
Research done in the field showed that urban heat islands appear in areas where wind velocity and evapotranspiration are decreased (less green areas) and level of waste heat is greater. Field research in the city center of Rijeka and on the pilot field at the location of the University Campus (outside center in less built area) was done during summer season of 2011, 2012. and 2013. The task of the field research was primarily to identify local materials which use can help reduce or mitigate the effect of additional heating in the urban environment caused by emission of heat from pavement surfaces but also to analyze the impact of other parameters (humidity, wind speed, presence of water, traffic intensity) on the heating of urban pavement surfaces. In the paper short overview of the parameters influencing heating of urban pavement surfaces will be done and results of the temperature measuring on cross section situated in the city centre

Keywords: pavement surfaces, pavement materials, urban areas, urban heat island, temperature

1 Introduction

Modern urban areas have typically darker surfaces and less vegetation than their surroundings. These differences affect climate, energy use and habitability of cities [1]. Materials commonly used in urban areas, such as asphalt and concrete, have significantly different thermal and optical properties than the surrounding rural areas. As vegetation and natural surfaces are replaced by asphalt and concrete surfaces for roads, buildings and other structures necessary to accommodate growing population, heat islands are developed; urban materials alter energy balance of an urban surface as they absorb, rather than reflect, the incoming solar radiation causing surface temperatures and overall ambient temperatures to rise. Lack of vegetation in urban areas also affects the energy balance, as the natural cooling of the surface by evapotranspiration is minimised [2]. The phenomenon of urban heat island (UHI) is related to positive thermal balance created in the urban environment because of the increased heat gains like the high absorption of solar radiation and the anthropogenic heat, and

the decreased thermal losses. Uncontestably, UHI is the most documented phenomenon of climate change and is very well documented for various geographic areas of the planet [3,4]. The impact of pavements on the development of UHI is very important. Many recent studies have shown that paving surfaces play a very determinant role on the overall urban thermal balance [5,6]. Pavements cover a quite high percentage of the urban fabric and contribute highly to the development of UHI. Paved surfaces in Europe and USA, consist mainly of asphalt and concrete surfaces that present high surface temperatures during the summer period [4, 7].
The aim of this paper is to present part of the results of temperature measurements on different types of pavement surfaces. Measurements were conducted in the City of Rijeka (Croatia) and are first known to the authors measurements of this kind conducted in Croatia. Measurements were conducted during the summer period when the temperature of road surface is reaching its peak. Analysis of the results will be used to comment possible parameters that can contribute to increase or to the decrease the temperature of urban pavement surfaces.

2 Pavements and urban climate

As was stated in the introduction, pavements affect strongly the urban climate. Their thermal balance is determined by the amount of the absorbed solar radiation, the emitted infrared radiation, the heat transferred by convection to the atmospheric air, the heat stored into the mass of the material and the heat conducted to the ground. The thermal balance of pavements and its impact on urban climate is analysed using experimental and computational simulation techniques. Microscale measurement techniques provide detailed information on the thermal conditions of the studied areas and allow a deep understanding of the corresponding thermal processes. Most of the microscale experimental studies have been performed using infrared thermography or conventional temperature measurements using thermocouples. The use of thermocouples to measure surface temperatures is a well known and accurate technique provided that a very good contact is achieved between the surface and sensors [4].

2.1 The role of the parameters that affect pavement heating

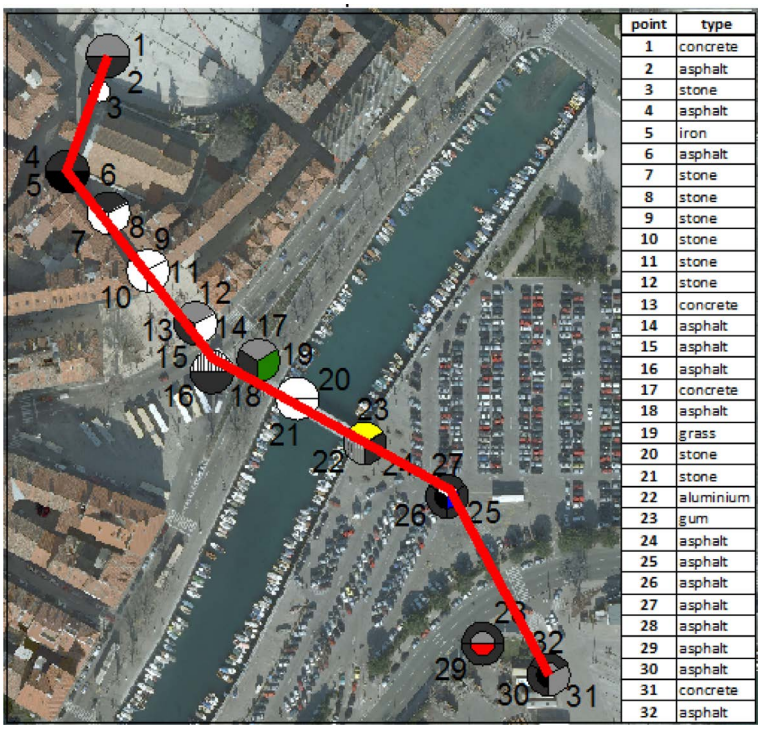
As was stated in the introduction, urban areas typically have surface materials which have a lower albedo than those in rural areas. As a result, the built environment generally reflects less and absorbs more of the Sun`s energy. This absorbed heat increases surface temperatures and contributes to the formation of urban heat islands. The value of the reflectivity is determined by the colour of the material and its roughness. Light colours present a lower absorptivity to the visual spectrum of solar radiation, while the specific absorptivity to the infrared part of the radiation is quite independent of the perceived colour [3, 4]. Numerous studies have been performed to correlate the impact of the colour of pavement materials on their surface temperature and sensible heat release. The research, conducted by Doulos et all [8] in which behaviour of 93 samples of commercial pavement materials were analysed under the same insolating conditions, has pointed out those analyzed materials which, under the determined micro-climate conditions (Athens, Greece) can contribute to reducing the UHI, reducing the electricity consumption and improving thermal conditions in open areas.
Materials emit long wave radiation as a function of their temperature and emissivity. High emissivity values correspond to good emitters of long wave radiation and can readily release the absorbed energy [3, 9]. Several studies were performed to understand the impact of the emissivity on the thermal performance of materials used in the urban environment. The research, conducted by Syneffa et all [9] showed that emissivity is the most important factor affecting the surface temperature of the materials during the night period.
Besides these properties, the thermal behaviour of urban surfaces plays an important role in the UHI development. This behaviour is largely determined by the density, specific heat

capacity, thermal conductivity and thermal admittance coefficients of the used materials. Heat capacity refers to ability of material to store heat, while thermal conductivity is ability of material to conduct heat. Both entities determine thermal diffusivity of material, which is an important indicator of how easily heat can penetrate into material. The ability of material to store and release heat is defined by the thermal admittance which is a product of thermal conductivity and heat capacity. Increased thermal conductivity of paving surfaces contributes to transfer faster the heat from the pavements to the ground and vice versa [4]. The research, conducted by Gavin et all [10] have showed that with increasing conductivity the average maximum surface temperature decreases, while average minimum temperature increases. In the same study the same correlation is showed for thermal capacity.
Water also plays a very important role. In permeable pavements, water passes to the soil. It evaporates when the temperature of the material increases and thus lowers a pavement surface temperature. Evaporation depends on moisture content in the material and atmosphere and depends of materials temperature [4, 11].
Use of high-albedo urban surfaces and planting of urban trees are inexpensive measures that can reduce summertime temperatures. When trees are planted and albedo is modified throughout an entire city, the energy balance of the whole city is modified, producing city-wide changes in climate. Phenomena associated with city-wide changes in climate are referred to as indirect effects [1].

3 Pavement surface measurements in the City of Rijeka

3.1 Overview of the published results and findings

An extensive study of the pavement heating was conducted during summer seasons 2011., 2012. and 2013. in the City of Rijeka. Part of the research was done in the city centre where temperature of surfaces made of different materials (asphalt, concrete, stone, granite) were compared and during 2013. data were collected at the pilot field at the pavement test sections at the location of the Campus of the University of Rijeka (located outside of the centre) at the higher elevation (150-180 masl). In this paper part of the results of the study conducted in the city centre will be presented.
Interesting analyses of the influence of different parameters on the pavement surface temperature can be done if considered a cross section in urban area. At the Picture 1 the cross section defined in the Centre of Rijeka City is shown together with the details about surface materials. In this case the cross section is situated partly in the intensively built pedestrian zone, partly on canal and partly on the big parking area. Few streets with high traffic volume are taken into analyses too and also pedestrian bridge made of aluminium and glass. At the location the temperature was measured during 3rd and 4th July 2012. during 24 hours in period of 30 minutes.
The results [12, 13, 14] showed that asphalt is certainly, regarding thermal properties, the most unfavourable material to be used in urban areas. Differences have been noticed if lighter aggregate (limestone) is used or if asphalt pavement is in use for some time and has washed surface. Concrete can be estimated as more favourable than asphalt for urban pavements because exposed to the same temperature conditions develops lower surface temperatures and consequently realises less heating to the surrounding air.
The chart from Figure 1 shows changes in the air temperature and surface pavement temperature measured during July 2012 at the locations near cross section described and analysed in paragraph 3.2. From the picture is evident that asphalt surface has highest surface temperature compared with stone and concrete placed in the same conditions [15].
Except the type of material used for pavements the Study pointed out some other parameters important for formation of urban heat island in the cities: position of the surface inside urban area, presence of water and exposure to isolation are among most important.



point	type
1	concrete
2	asphalt
3	stone
4	asphalt
5	iron
6	asphalt
7	stone
8	stone
9	stone
10	stone
11	stone
12	stone
13	concrete
14	asphalt
15	asphalt
16	asphalt
17	concrete
18	asphalt
19	grass
20	stone
21	stone
22	aluminium
23	gum
24	asphalt
25	asphalt
26	asphalt
27	asphalt
28	asphalt
29	asphalt
30	asphalt
31	concrete
32	asphalt

Figure 1 Cross section – location and materials

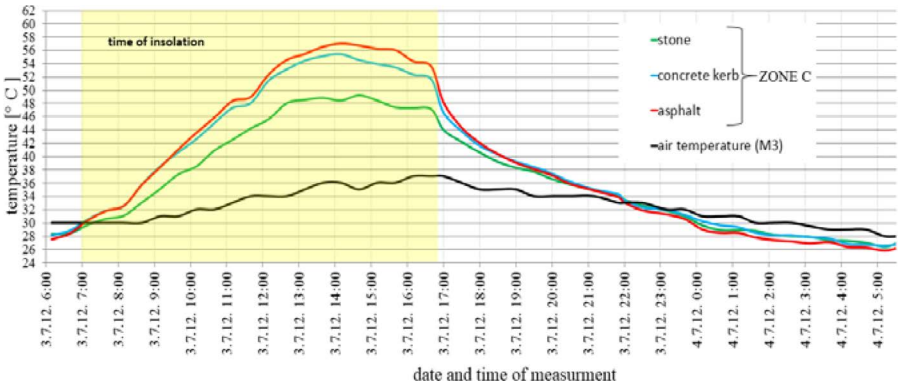


Figure 2 Whole day temperature measurement on different pavement surfaces on 3rd July 2012. [15]

3.2 Cross section in the City centre of Rijeka

The temperatures of the air and pavement surfaces measured at 7 a.m. and at 1 p.m. at the cross section (Figure 1) are showed at the chart (Figure 3). It is evident that the difference in air temperature and surface temperature in the morning period is significantly lower than in afternoon when the pavement at specific locations is more than 10°C warmer than air.
The results are showed in the way that temperature of different sub-areas can be compared and sub-areas are showed both with pictures and symbols.

The influence of the presence of water can be established as the factor that decreases temperature of the air as well as the temperature of the surfaces around the water, in this case the canal. Even being very small (positions 17-19) the green zone with some trees has positive effect on the pavement temperature nearby and they are for few degrees lower than on the pavement open to the insolation.
Temperature of the closed and intensively build area (square surrounded with houses) is slightly lower than temperature measured on the open and exposed area of the parking. The conclusion can be that it has to do with the type of surfaces as well as with the duration of exposure to the direct insolation. Pavements in pedestrian zone are made of stones and that kind of pavements show better characteristics regarding heating than asphalt pavement (see Figure 1) [12, 13].
Slightly higher temperatures were also measured at the position of traffic lines on the roads (15-16, 28-29) and it can be presumed that the influence of intensive traffic is negative, e.g. that intensive traffic volumes can contribute to the increase of pavement temperature, even not very much.

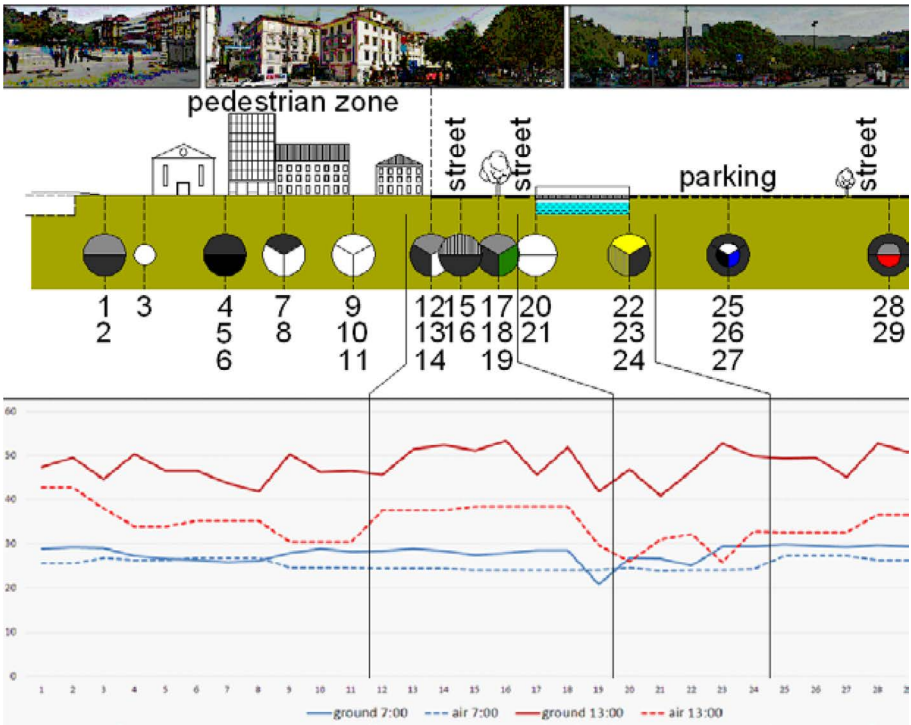


Figure 3 Cross section – temperatures of the air and pavement

4 Conclusion

It is known that pavements surfaces play a very determinant role on the overall urban thermal balance. Different are the parameters that influence that relation, some are connected with the material properties and some with the location of the urban area. Previous analyses done by the authors pointed out which of the materials have positive influence on UHI. From data collected at the field study of pavement temperatures in the City of Rijeka (Croatia) in this paper a temperature of one central area is shown. Since the cross section included

areas within pedestrian zone and the zone of densely built areas as well as areas near canal and large parking areas, it was possible to analyse environmental conditions that affect the temperature. It turned out that more protected areas within the built-up area (so called urban canyons) that are not exposed to constant sunlight, the areas near water and areas within greenery, have lower average temperature than parking surfaces and traffic lanes that are exposed to traffic and direct sunlight.
Further analyses that will include calculation of the average temperature in the zone built of different materials as well as data about solar radiation must be done. In that way, more precise conclusions can be done.

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