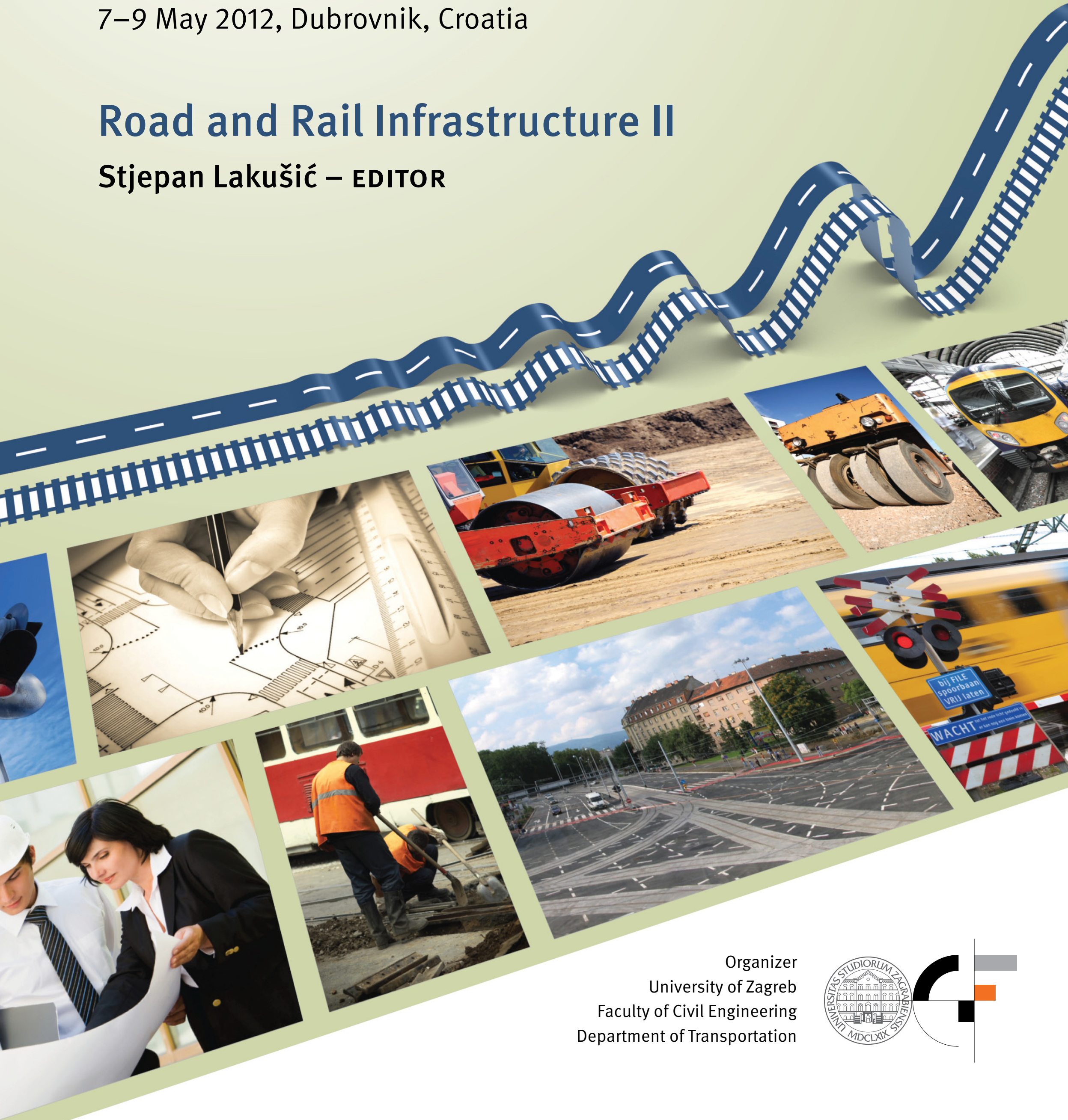
CETRA^{2012}

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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CETRA^{2012}
2nd International Conference on Road and Rail Infrastructure
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TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
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PAVEMENT SURFACES IN URBAN AREAS

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Abstract

Areas that were once permeable and moist become impermeable and dry because of urban areas development, and constant construction of city roads and other urban infrastructure. This considerably reduces evaporation, which helps in air temperature reduction. Complex urban geometry prevents the natural wind flow, while the urban canyons absorb solar energy reflected and absorbed by building walls, which further increases the average temperature of urbanized areas in relation to temperature of surrounding rural areas. Research shows that the use of appropriate materials for traffic surfaces and building roofs can reduce the increased warming effect, the so called heat island effect, in the center. Dark materials (e.g. asphalt) are often used in construction and rehabilitation of traffic surfaces without taking into account that they absorb more energy than lighter material (e.g. concrete). All of the above directly affects the formation of urban heat islands. This phenomenon is thoroughly investigated in the U.S., Australia and partially in some European studies and is recognized as a significant environmental problem of cities today.
During the summer of 2011 temperature tests were made on different types of pavement surfacing, on pedestrian and other roads in the Rijeka city centre. This paper will present the results concerning the temperature of different types of road surface that are commonly found in city centres, such as asphalt, stone, concrete surfaces and land surfaces. Tests were conducted during the summer months when the road surface temperature is reaching its peak. The behaviour of these surfaces considering sunlight, colour and traffic load will be analyzed and a comparison with air temperature will be shown. A result analysis will be used to define the possible heat island effect reduction measures.

Keywords: pavement surfaces, urban areas, temperature, asphalt, concrete

1 Introduction

Modern urban areas are characterized by dark surfaces and less vegetation. This great amount of asphalt, concrete, stone and other similar surfaces absorbs a greater proportion of solar radiation during the day which is reradiated during the night. The result is elevated temperature in urban areas. This temperature difference between urban, suburban and rural areas is what constitutes the urban heat island effect. Roads and parking lots are frequently paved with asphalt that absorbs most of the solar radiation. The sun´s energy is converted into thermal energy so pavements get hot, heating the air around them and contributing greatly to the urban heat island effect. The use of appropriate materials in heat island reduction is a subject of many studies [1]. Pavements are part of the problem, but pavements can also be part of the solution (Fig. 1). The use of appropriate materials (cool materials) can improve thermal comfort conditions. One of the strategies in solving that problem is usage of 'cool pavements'. Cool pavements include a range of established and emerging technologies that communities are exploring as a part of their heat island reduction efforts. The term currently refers to paving materials that reflect more solar energy, enhance water evaporation, or have been otherwise modified to remain cooler than conventional pavements. Cool pavements can be created with existing paving technologies (such as asphalt and concrete) as well as newer approaches such as the use of coatings or grass paving [2].

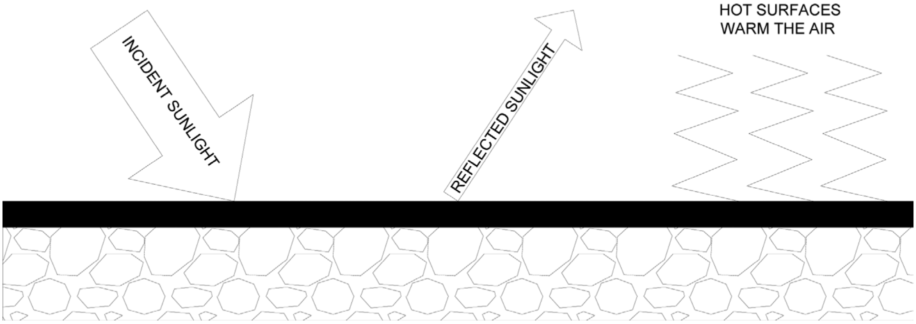

Figure 1 Behaviour of pavement structures due to incident sunlight

The aim of this paper is to present the results concerning the temperature of different types of pavement surfaces that are commonly found in city centres, such as asphalt, stone and concrete. Tests were conducted during the summer months when the road surface temperature is reaching its peak. The behaviour of these surfaces, considering the sunlight will be analyzed and a comparison with air temperature will be shown. Results analysis will be used to define the possible measures for the heat island effect reduction.

2 Thermal properties of cool pavements

The best known characteristic of urban climate is that air temperatures are higher than those in the surrounding rural areas at night. Urban geometry and thermal properties of urban surfaces have been found to be the two main parameters influencing urban climate [3]. The influence of thermal material properties on urban climate will be discussed in this paper.
The effect of materials on the temperature of the localized atmosphere is a rapidly expanding research area. Basic research in this area is directed at the material colour and composition and their ability to reflect or absorb (and emit) solar radiation. The colour and composition of the materials greatly affects the temperature of the material exposed to solar radiation. Heat energy from absorbed solar radiation will eventually enter the surrounding atmosphere, causing localized heating [3]. In this sense, albedo and infrared emittance are important material characteristic.

2.1 Albedo and infrared emittance

Albedo is a measure of material´s solar reflectivity.It is the degree to which material will reflect incoming solar radiation (all light from the sun including infrared, visible and ultraviolet light). Albedo is measured on a scale of 0 to 1. Materials on the low end of the scale absorb solar radiation, while materials on the upper end of the scale reflect solar radiation. Generally, materials that appear to be light–coloured in the visible spectrum have high albedo and those that appear dark–coloured have low albedo (Fig. 2). Because reflectivity in the solar radiation spectrum determines albedo, colour in the visible spectrum is not always a true indicator of albedo [4].

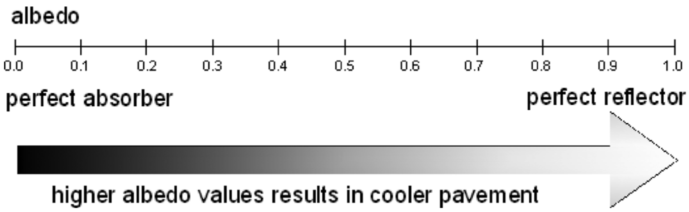

Figure 2 Definition of albedo

Infrared emittance is a measure of the material´s ability to release absorbed heat. It specifies how well a material radiates energy away from itself as compared with a black body operating at the same temperature. It is measured on the scale from 0 to 1 [5].
Various studies have been performed for better understanding of thermal and optical performance of materials used for pavements. Asaeda et al. 1996 have reported experimental study results where the impact of different paving materials was tested during the summer period. Results show that surface temperature is significantly higher for asphalt than for concrete and soil. Berg and Quinn 1978 reported that white painted roads with albedo close to 0,55 have almost the same temperature with the ambient environment, while unpainted roads with albedo close to 0,15 were approximately 11°C warmer than air.

3 Analysis of pavement surface measurements in the City of Rijeka

The City of Rijeka is the largest Croatian port and the third largest city in Croatia. According to the Kepen classification, the City has moderately warm and humid climate. The average temperature is 13.8°C, which means that the average temperature in January is 5,6°C, while the average temperature in July is 23,3°C.

3.1 Description of locations

During the summer period of 2011 measurements of pavement surface temperature were carried out in the City of Rijeka. 40 different test points in the centre of the City were selected. Test points were on different surfaces (asphalt, concrete, stone...), located in pedestrian areas or areas exposed to vehicle traffic. To determine the influence of insolation, two all day measurements were carried out (12.07.2011. and 15.09.2011.). In total, 80 measurements were carried out at each test point out of which 35 measurement were carried out during the all day measurements. The remaining measurements were carried out during the daily maximum temperatures. Test points were located at one busy street in the City (Riva Boduli), on a pedestrian zone and bus station connection (Jelačić square) and at the main pedestrian zone (Korzo) (Fig. 3).

Figure 3 Location of all test points Riva Boduli street (left), Jelačić square (middle), Korzo (right)

The result of analysis for test points 1 and 3 at Riva Boduli street location, test points 1 and 2 at Jelačić square location and test points 1 and 2 at Korzo location will be discussed. Test points description is given at Table 1.

Table 1 Test points description

Location	Number of test point	Surface	Traffic load	Period of insolation (12.07. and 15.09.)
Riva Boduli	B1	Stone	Pedestrians	8:30 – 20:30 10:00 – 18:00
Riva Boduli	B3	Concrete	Pedestrians	9:00 –20:30 10:00 – 18:00
Jelačić square	J1	Asphalt	Vehicle	7:00 – 17:15 8:30 – 16:30
Jelačić square	J2	Concrete	Pedestrians	7:00 – 17:15 8:30 – 16:30
Korzo	K1	Stone	Pedestrians	10:45 – 17:30 9:30 – 13:30
Korzo	K2	Stone	Pedestrians	8:00 – 10:40 8:30 – 9:30

3.2 Analysis of the results of pavement surface temperatures

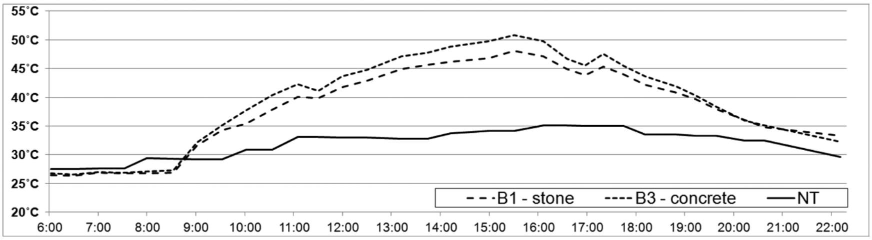

Figure 4 Daily change of surface and air temperature on stone and concrete (July 2011.)

Fig. 4 shows a daily change of surface and air temperature at test points B1 and B3 during the all day measurement (12.07.2011.). Test point B1 (stone) has the maximum measured temperature of 48,1°C, while the maximum measured temperature at test point B3 (concrete) is 50,8°C. Maximum temperature differences between test points B1 and B3 are 3°C. At the same time temperature difference between test point B1 and air is 13,9°C, while the difference between test point B2 and the air temperature is 15,6°C. Until 9:00am both test points are not exposed to sun radiation and differences in temperature between both test points are minimal and lower than air temperature. Microlocation of test points (proximity of the sea) may cause this phenomenon. From around 9:00am surface temperature of both test points increases and reaches its maximum around 3:30pm. From that point, until around 8:30pm pavement surface temperatures decrease, but the difference between test points B1 and B3 and the difference between individual test point and air is present. In the same time, slower cooling of stone materials is visible, which makes concrete a more suitable material for urban areas usage.

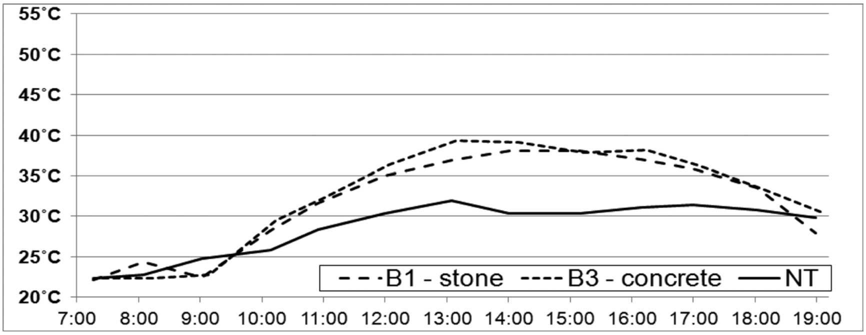

Figure 5 Daily change of surface and air temperature on stone and concrete (September 2011.)

Fig. 5 shows a daily change of surface and air temperature at the same test points (B1 and B3), during the all day measurement (15.09.2011.). Temperature increment shows the same trend like the measurements on 12.07.2011. do. The differences are in maximum measured temperatures which are around 10°C lower than the ones measured on 12.07.2011. At around 2:00pm a decrease in temperatures is recorded. It is evident, from Fig. 4, that summer temperatures reach their maximum at around 3:30pm, while autumn maximums (Fig. 5) occur earlier, around 2:00pm.

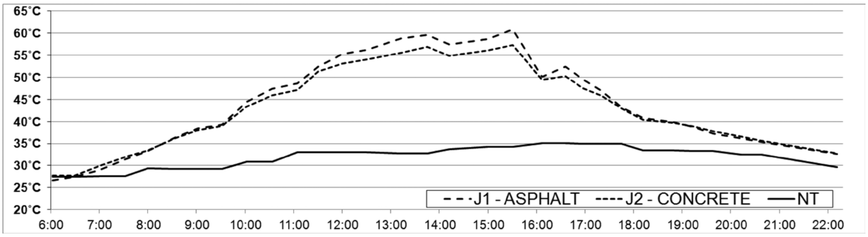

Figure 6 Daily change of surface and air temperature on asphalt and concrete (July 2011.)

Fig. 6 shows a daily change of surface and air temperature at test points J1 and J2 during the all day measurement (12.07.2011.). Test points are located at a bus station and pedestrian zone conjunction. Test point J1 (asphalt) has the maximum measured temperature of 60,9°C, while the test point J2 (concrete) has 3,6°C lower temperature and even 26,7°C lower air temperature at the same time. Even with the usage of insolation materials, the surfaces behave similarly, although the temperature of the asphalt surface is higher than the concrete surface temperature.

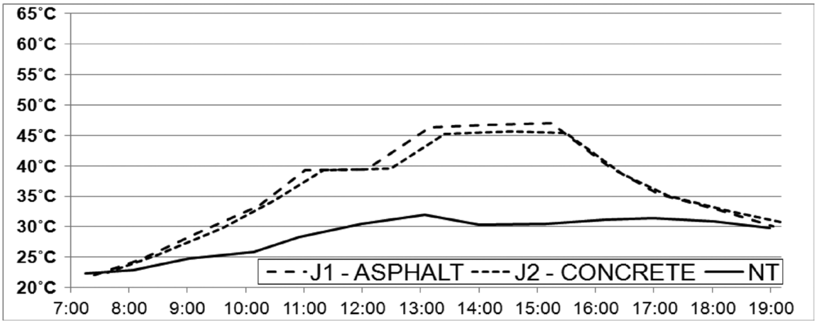

Figure 7 Daily change of surface and air temperature on asphalt and concrete (September 2011.)

Fig. 7 shows a daily change of surface and air temperature at the same test points (J1 and J2) during the all day measurement (15.09.2011.). Temperature increment shows a similar trend to the measurements conducted on 12.07.2011. The differences are in maximum measured temperatures which are, for asphalt, nearly 14°C lower than in summer period. The maximum temperature differences of both test points are minor (around 1°C) and period of maximum differences is reduced.

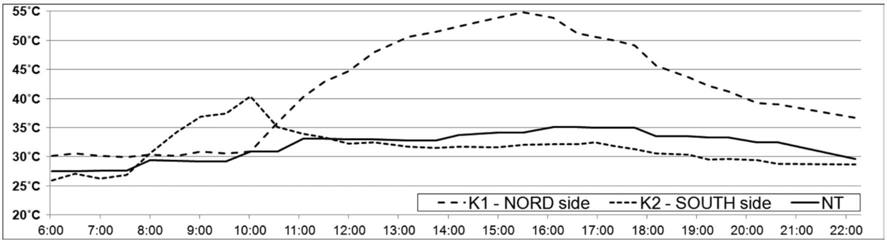

Figure 8 Daily change of surface and air temperature on stone (July 2011.)

Fig. 8 shows a daily change of surface and air temperature at test points K1 and K2 during the all day measurement (12.07.2011.) Test points are located at the main pedestrian zone in the City. The specificity of the test points is different insolation time. Temperature of K1 test point rapidly grows with the appearance of insolation. The maximum measured temperature was 54,8°C. Temperature of K2 test point moderately increases (time of insolation) and the maximum measured temperature was 40,4°C. Insolation period for test point K2 stops at around 10:30am, so the temperature from that point until the end of measurements decreases. In the same period, insolation of test point K1 starts so the temperature from that point rapidly increases. Because of the different period of insolation, temperature differences of test points are pronounced (more than 20°C). From around 12:00am temperature of K2 test point is lower than the air temperature.

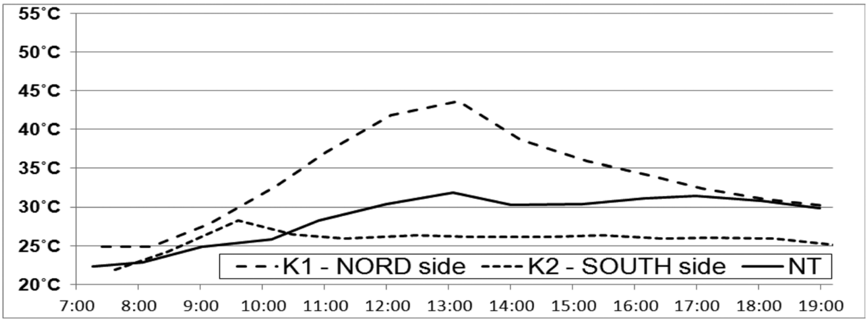

Figure 9 Daily change of surface and air temperature on stone (September 2011.)

Fig. 9 shows a daily change of surface and air temperature at the same test points (K1 and K2) during the all day measurement (15.09.2011.). Temperature increment of both test points shows a similar trend like the measurements in July. Temperature of test point K1 reaches its maximum at around 1:30pm. From that point surface temperature decreases, which is a result of termination of insolation. Test point K2 reaches its maximum at around 9:30am and from that point the reduction in surface temperature is evident. From around 10:30am surface temperature of test point K2 is lower than air temperature. That can be a result of short insolation time.

4 Conclusion

The temperature in the City is influenced by a range of factors which we can or can't control. What we certainly can control is the building material. As the pilot study of measuring temperatures in the City of Rijeka shows, major factor effecting the surface temperature is the sun's radiation. One of the strategies to mitigate urban heat island effect is the usage of high albedo surface materials, usage of porous pavements and increment of urban vegetation.

In this paper we presented results of pavement surface temperature measurements conducted during the summer of 2011, in the City of Rijeka. Results indicate that concrete and stone materials achieve lower temperatures in peak hours. Results also indicate that concrete is a more favourable material for usage in city centres, because it showed a lower level of temperature than asphalt, especially in peak hours (test points J1 and J2). Results show that insolation period has a major influence on surface temperatures. Test points that are in shade reach lower surface temperatures than those exposed to insolation.

High temperatures can also cause damage to paving materials. In general, higher temperatures cause materials to expand and then contract as they cool. For concrete this can lead to cracking and even failure. For asphalt this can cause rutting and other surface deformation. Extra research is needed to further analyze characteristic of pavement materials and to highlight the benefits of using cool materials from the point of life quality but also the increment of durability of materials sensitive to temperature change.

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