

## **PAVEMENTS COVERED FOR HEAT ISOLATION TO GET PEDESTRIAN THERMAL COMFORT**

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### **Abstract**

Civilization has been analyzed mostly with urbanization which coincides with the usage of stone and later concrete and steel in constructions. Nowadays we have been realized that construction materials used for houses, apartments, roads and pavements surrounding us create local microclimate which influences our living comfort. Local temperature increases due to asphalt roads and concrete pavements have recently been determined and they are remarkably effective in our everyday life. Usage of different types of aggregates in concrete mixtures to cast concrete pavement blocks might effective to decrease air temperature on the pavements. Therefore heat-resistant rocks were used to produce different sized aggregates where different plasters were produced from them to coat standard concrete pavement blocks. Pavement blocks plastered were then put under sun to test their surface temperatures. It was observed that heat-resistive materials used in plaster concretes influence heat distribution in the blocks and surface temperature of the concrete pavement blocks.

**Keywords :** Pedestrian comfort, heat-resistive materials, concrete pavement blocks.

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## **YAYALARIN SICAKLIKTAN RAHATSIZ OLMAMALARI İÇİN ISI İZALASYONU AMACIYLA KALDIRIMLARIN KAPLANMASI**

### **Özet**

Uygarlık genellikle şehirleşmeyle birlikte değerlendirilir, bu gelişim de önce doğaltaşların daha sonra beton ve çeliğin inşaat işlerinde kullanılmasıyla sağlanmıştır. Günümüz şartlarında şehirlerde etrafımızı saran evler, apartmanlar, yollar, kaldırımlar ve bunların yapıldığı farklı malzemeler nedeniyle, insanların hemen etrafında onların yaşam konforunu etkileyen mikroklimatik bir etkinin varlığı hissedilmeye başlanmıştır. Son zamanlarda yapılan incelemelerde, etrafımızdaki lokal sıcaklığın asfalt yollar ve beton kaldırım taşları nedeniyle de yükseldiği belirlenmiştir, bu artış insanların günlük yaşantılarını etkilemektedir. Beton kaldırım taşlarının yapılmasında kullanılan malzemelerin farklılaştırılmasıyla, insanları rahatsız eden yaya kaldırımı üzerindeki havanın sıcaklığı belki düşürülebilir. Bu fikirden yola çıkarak bu çalışmada, ısı geçirgenlik özelliği düşük olan, farklı kayaçlardan elde edilen, farklı tane boyut içerikli ve farklı özellikteki agregalardan değişik özellikli sıvalar üretilmiştir. Bu sıvalarla da standart boyuttaki beton kaldırım bloklarının üzerleri sıvanmış, kaplanmıştır. Test edilmek üzere hazırlanan kaplanmış kaldırım blokları, güneş altına konularak bunların yüzey sıcaklık değişimleri ölçülmüştür. Kaldırım bloklarının yüzeyini kaplamak amacıyla üretilen sıvaların üretildikleri agrega özelliklerinin, özellikle bunların ısı yalıtkanlık özelliklerindeki farklılıkların, testi yapılan kaplamalı kaldırım bloklarının yüzey sıcaklıklarını etkilediği gözlenmiştir.

**Anahtar Kelimeler:** Yaya konforu, ısı yalıtım malzemeleri, beton kaldırım blokları.

### **1. Introduction**

It is common that outside temperatures in urban areas are mostly higher than countryside. This may have certain advantages in wintertime but disadvantages in summertime due to their uncomfoting influences. Concrete have been used nowadays to build apartment blocks, houses and roads. Most of the pavement blocks in urban areas are

also molded by using concrete mixtures. It is common that concrete and natural stone slabs on urban roads and pavements are the main reasons of high temperature island occurrences in cities. Heat arrived from sun by radiation in summertime, heats up earth surface and cause temperature differences due to shading and surface materials' properties. Temperatures on earth surface layers which stayed whole day under the sun reach very high levels which might create local microlevel climate effects. Heated up areas are then formed "heat-islands" around them (Fig.1). Even though, these areas can continue to supply their deposited heat after sunsets, until their body temperature will reach the same level with their environmental air temperature. In hot sunny days, heating of the concrete structures, roads, walls, pavement blocks can reach a certain level which disturbs humans.

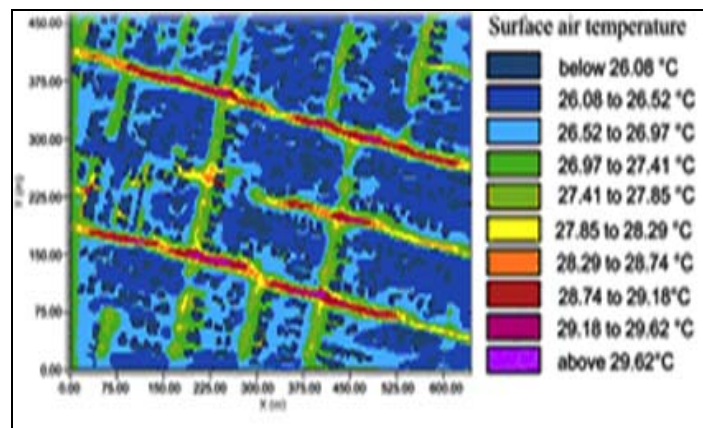


Figure 1. Temperature measured in a research performed in Los Angeles (US) on a sunny summer day, (at 02:00 pm, at a height of 1.5 meter from the ground surface), [1].

## 2. Procedure to Get Pedestrian Comfort

"Heat-island" has been researched for a while and therefore any decreasing actions on their temperatures are welcomed by societies. One simple way is watering sun heated roads, pavements and any other locations in summer. This action decreases their surface temperatures and gives certain degree of relaxation for people living nearby. But watering is costly due to water usage and their supply. Shadowing of the roads and especially

pavements are also one of the methods used by municipalities. Trees near pavement areas, curtaining over the sunny narrow streets, bazaars, are mostly applied methods. In researches, it has been already presented that cool pavements cause significant reduction in surface air temperature. In Los Angeles city (US), there are official applications about the heat islands [2] to decrease air temperature just above the roads and pavements. In this municipality works; workers coated selected city streets and pavements by predefined gray colored cool materials [3]. Eventually, summer temperature on the tested local area had been surveyed and certain declines in air air temperatures (local) were reported for these projected Los Angles heat-island applications. It was reported [3] that two modified albedo (whiteness) scenarios were studied in Los Angeles application: a moderate and an extreme increase in albedo scenario. It was found that for the first case, the temperature decrease at 2.0 meters height (from the ground surface) was as high as 1.5 °C, (Celcius), and for the second case as high as 2.2 °C. The typical temperature change pattern is a decrease during daytime and little or no decrease during the night [3].

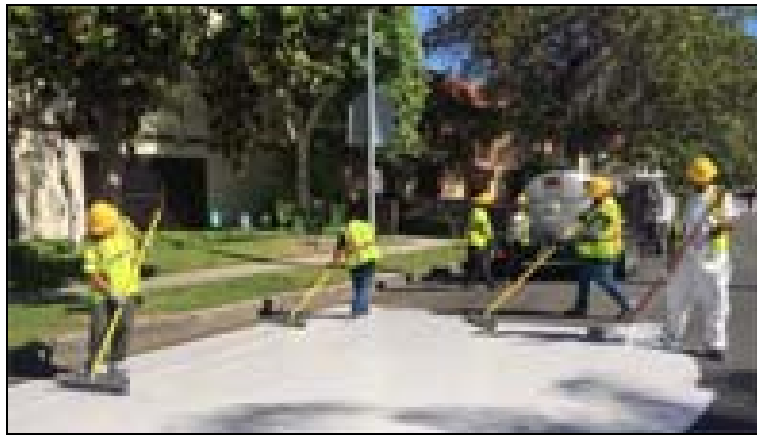


Figure 2. Painting project for selected Los Angeles (US) streets to decrease heat island influences of local roads and pavements [3].

The impact of temperature depression at heat-islands would have been even greater if the albedo of all roads and pavements was increased. It is obvious that connection roads, streets, pavements, pedestrian areas, buildings roof & walls and all similar constructed surfaces increase urban areas temperatures. In this subject, Akbari analyzed the situation in cities

and reported heat island mitigation solutions [5]. Besides this research, reflective pavements were applied to an urban park in Athens (Greece) by Santamouris et al. to reduce heat radiation [6]. They wrote that usage of cool (white materials which were presenting high reflectivity in infrared radiation and high emissivity) paving materials reduced peak ambient temperature during a summer day up to 1.9 °K, (Kelvin). They reported also that temperature of the park itself decreased up to 12 °K. In another study researchers were concentrated on cool material properties and their usage as asphalt road and concrete block coatings. They reported that [7] usage of cool materials “contribute to the mitigation of heat island effect”. Santamouris et al. [7] presented also work of Synnefa et al. [8] which showed visible and infrared photograph of thin concrete plates (Fig. 3). These photographs (Fig. 3), especially the infrared images differentiate surface temperature of the thin concrete plate clearly. Infrared images demonstrated that plate numbered 1 and 4 (they had white color coatings) had lower surface temperatures (7.5 °K lower than reference plate-3) and plate-2 (it had black colored coating) on the other hand had higher surface temperature (15.0 °K higher than reference plate-3) [7]. Synnefa et al. tested 16 concrete plate samples in their research and 15 of them were coated with different cool materials (plate 3 was extra reference plate, it has no coatings). Synnefa et al. reported that cool coating materials used in their research were available in international markets. These materials are general coating materials used in construction and civil works [8]. Description and colors of these coatings are as follows;

- S1 Aluminum pigmented acrylic coating, (Silver gray color),
- S2 Acrylic, ceramic coating, (White color),
- S3 Acrylic, elastomeric coating, (White color),
- S4 Acrylic, elastomeric coating, (White color),
- S5 Alkyd, chlorine rubber coating, (White color),
- S6 Aluminum pigmented, alkyd coating, (Silver gray color),
- S7 Emulsion paint, (Black color),
- S8 Acryl-polymer emulsion paint, (White color),
- S9 Acrylic latex, (White color),

- S10 Aluminum pigmented coating, (Silver color),
- S11 Acrylic insulating paint, (White color),
- S12 Aluminum pigmented acrylic coating, (Silver color),
- S13 Epoxy polyamide coating, (White color),
- S14 Acrylic paint, (White color),
- S15 Uncoated tile (reference concrete plate), (White color),
- S16 Acrylic elastomeric coating, (White color).

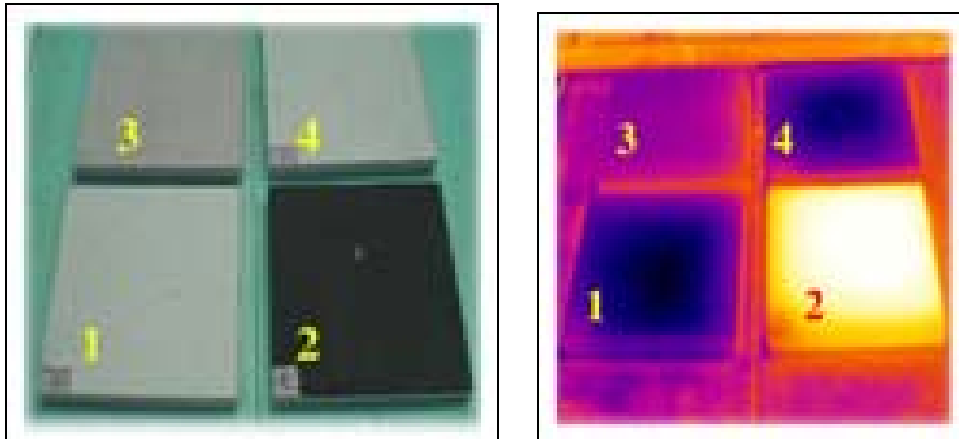


Figure 3. Visible (left) and infrared (right) images of the concrete plates which were coated with different cool materials. Concrete plates were put under sun for a while and photographs were then taken. Cool materials, coatings, used on the numbered concrete plates are; Acryl-polymer emulsion paint (white color) for plate-1; Emulsion paint (black color) for plate-2; Uncoated tile (reference) (white color) was plate-3; Alkyd, chlorine rubber coating (white color) for plate-4, [7].

Synnefa et al. pointed that mean maximum daily surface temperature measured from coated plate surfaces during day time of August and September increased up to 67.92 °C on the test plate-7, (S7), which had emulsion black paint as a surface coating. Minimum mean daily surface temperature measured was 32.13 °C on the test plate-16, (S16). Mean surface temperature levels in this study demonstrate the importance of the surface coating effects.

Different approach in “heat island effect” was supplied by Yang et al. [9] and they reported that performance of heat island prevention works (pavement coatings etc.) in the canyon type locations was influenced mainly by the canyon geometry. They wrote that, in a high-density residential area, modifying pavements might change their surface temperature

slightly but this action had insignificant effect on the wall temperature (Fig.4) and building energy consumptions. Figure 4 illustrates some results of Yang et al. which were predicted and simulated temperature fluctuations for summer daytime of Phoenix (US). Figure 4a showed that increasing pavement albedo decreased the pavement surface temperatures considerably. Comparing Fig. 4a and Fig. 4b illustrates the influences of canopy.

Table 1. Daily (08:00-19:00) mean and mean maximum surface temperatures measured from concrete plates coated with different cool materials, [8].

Test Samples	August		September	
	Mean daily surface temp. (°C)	Mean max daily surface temp. (°C)	Mean daily surface temp. (°C)	Mean max daily surface temp. (°C)
S1	46.19	58.67	36.49	48.82
S2	33.15	40.79	27.78	35.07
S3	36.68	44.89	30.58	39.10
S4	34.68	43.17	29.06	37.30
S5	33.18	40.67	27.74	34.77
S6	44.85	56.85	36.39	47.77
S7	52.09	67.92	40.44	54.63
S8	32.82	40.73	27.90	35.52
S9	33.89	41.24	29.03	36.00
S10	44.25	54.83	36.78	47.08
S11	37.34	46.49	31.79	40.59
S12	41.72	50.68	34.79	43.50
S13	37.81	46.95	32.08	40.74
S14	33.25	39.63	28.91	35.12
S15	37.13	45.79	30.92	38.78
S16	32.13	38.28	28.63	36.07

Shading effects in residential areas cause gradual decrease of pavement surface temperatures. The resultant test curves like given in Fig. 4b have then step downward

inclinations in afternoons. Yang et al. stated [9] also that “with reduced road surface temperatures, the reflective pavement emitted less longwave radiation to the canyon environment. Nevertheless, more shortwave radiation was reflected that the combined effect of the reflective pavement was complicated”. Figure 4c presents surface temperatures measured on the building walls. During diurnal cycle, increasing pavement albedo resulted in a warming effect on building walls (in between 10:30 – 15:00 local time). These researchers then wrote that; “increased wall temperature indicated that reflected shortwave radiation outweighed reduced longwave radiation from the reflective pavement” during this time period. In other time, reflective pavement led to cooling of wall surface temperatures.

### **3. Materials and Methods**

To obtain similar local temperature decreases at heat island formed during summer daytime in Elazig, Turkey, heat- resistive materials (heat insulation minerals) which have been used in constructions industry are facilitated in this study here to produce heat sensitive floor coating materials, concrete plasters. Pavements in most of the city centers are covered usually by precast small sized, concrete blocks in Turkey. These small, 8 cm thick, concrete blocks are produced in different surface forms and shapes. Summer daytimes are very hot in Elazig. Weather temperature can reach up to 40 °C. People have their hot weather experiences in this city like all the other hot cities. They have obstructed themselves to go outside in between 11:00 – 16:00 o'clock. Uncomfortable conditions are disturbing people in heat islands in cities due to hot building walls, hot roads and hot pavements etc. They prefer to go soil and grass covered open areas which have lower outside temperatures. However, even those places are very hot during days of August in Elazig. High temperature conditions over the asphalt roads, concrete pavements, stone slap covered city squares are common in Elazig in these hot daytimes. Therefore as a first stage of this research here; concrete heat-resistive plasters which were prepared from different heat resistive rock aggregates had been applied over standard concrete pavement blocks. In



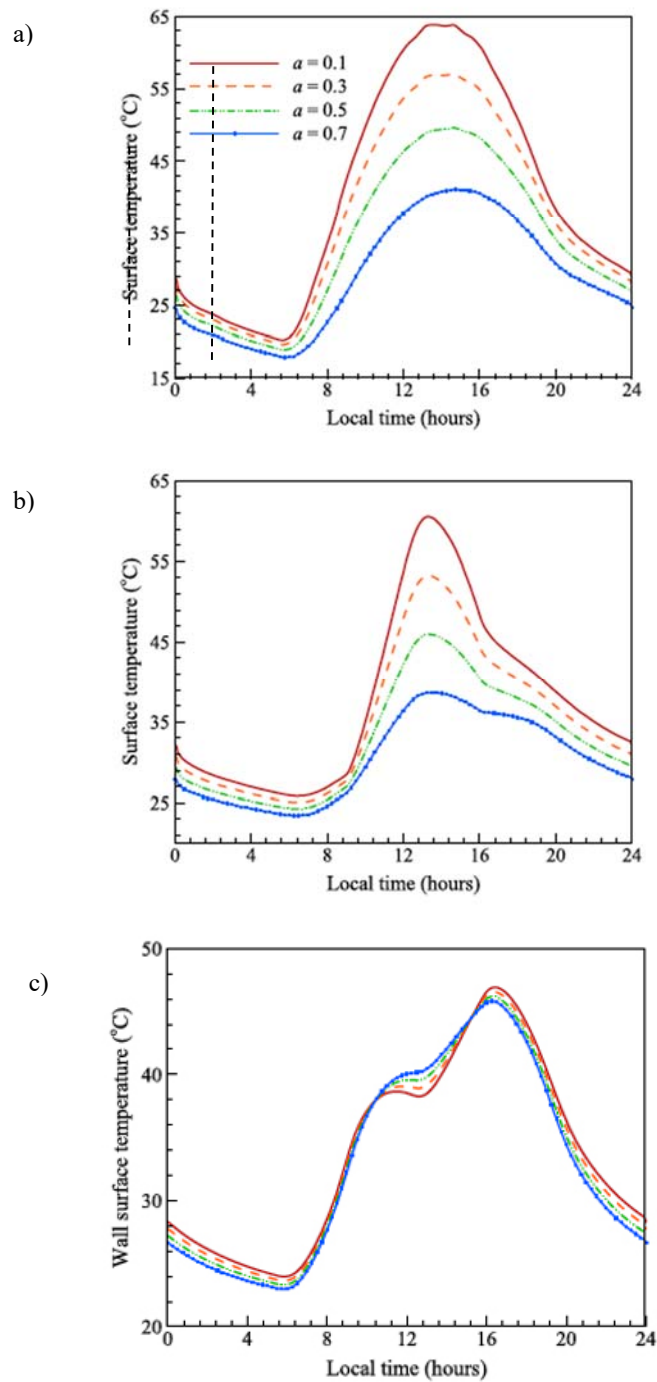


Figure 4. Average diurnal profiles of predicted temperatures with different albedo a) Temp. of pavement surfaces without canopy, b) Temp. of pavements located in a high-density residential area, with canopy; c) Simulated temperature of building wall surfaces in Phoenix (US) during 12-17 June 2012, [9].

the second stage, white colored cool coating materials were used additionally to cover some of the samples used in the first stage.

Pavements in Konya and Elazig city are mostly covered by means of small precast concrete pavement blocks (one of the pavement models is give in Fig. 5). They are 8 cm thick and sometimes colored in reddish and yellowish other than the concrete's natural grayish color. Their standard aggregate sizes, Portland cement and water mixture ratios are kept stable in factories where they are pre-shapely casted together with vertically applied pressure. Similar standard mixture ratios were used in this work to produce heat-resistive plaster concrete and different plaster samples were put on the standard pavement block surfaces as thick as 1.50 cm. This sample preparation work was like thick plastering application in construction works. Plastering mixtures which were prepared for covering the ordinary concrete pavements blocks were arranged in different aggregate types. Thus, standard concrete pavement blocks handled in this study had been coated with these especially prepared concrete plastering mixtures. The resultant heat-resistive concrete pavement blocks were then totally 9.50 cm in thickness (standard concrete thickness= 8 cm, and additional 1.50 cm of heat resistive plaster thickness), (Fig.5).

In order to compare effectiveness of heat-resistivity, 6 different types of rock aggregates were used separately to prepare 6 different heat-resistive plasters. These aggregate types were; Aksaray pumice, Nevsehir pumice, tuffs, perlites, white marble powders, Karapinar basic pumice (black in color). For each type of heat-resistive aggregate, 3 standard concrete pavement blocks were plastered in mining engineering laboratory of Selcuk University, (Konya, Turkey). That means, each plaster type, (made up from each aggregate type), was tested through 3 pavement blocks (Fig. 5). After application of plasters, samples had been regularly wetted until the plasters and standard concrete blocks were combined together totally.

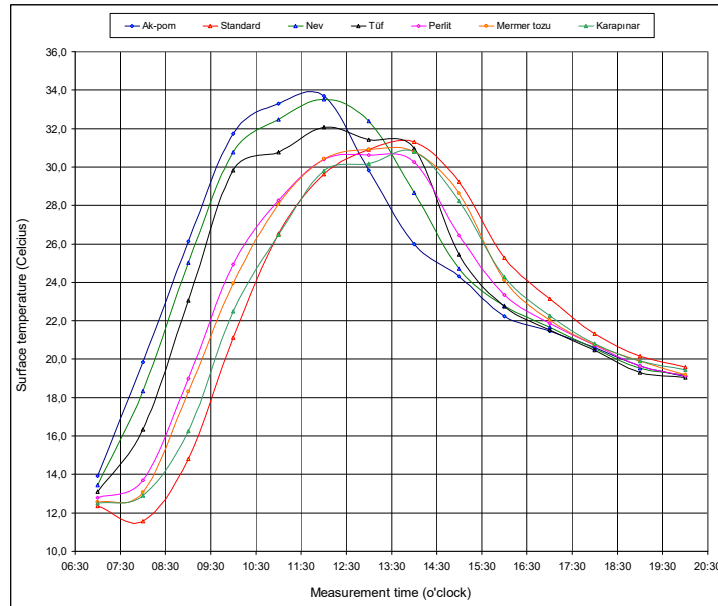


Figure 5. Heat resistant concrete pavement block samples, prepared for surface temperature tests by coating their top surfaces with especially prepared heat resistant concrete plaster.

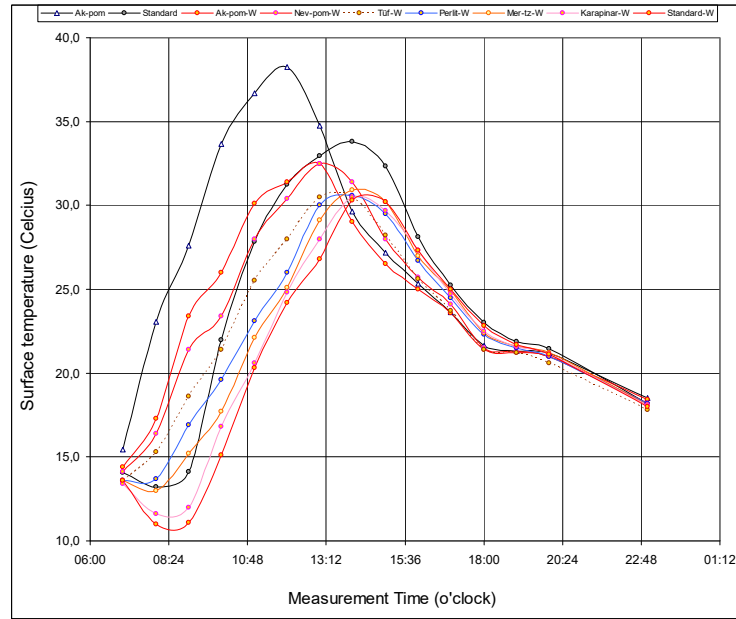
#### 4. Test Results

In this study 7 different concrete pavement blocks (each has 3 samples, then  $7 \times 3 = 21$  test blocks totally) were taken into tests. Surface temperature measurement tests were performed in Elazig city centre that means selected test location was an urban area which includes canopy effects. All the test samples were put on a flat floor under the sun in Fall season of 2017. First stage tests include all the heat-resistant concrete pavement blocks including the standard ones which were not plastered for reference data. After collecting surface temperature data for the first test stage, second test stage was started after applying cool coating materials (white colored) on one member of each 7 different concrete

pavement block group. White coating materials used here was polyester putty (filling) and coating material. This material has common usage in automotive maintenance activities in Turkey. In order to increase the coating material effectiveness, top surface of the heat-resistance concrete pavement blocks were painted with white colored oily synthetic paint. This paint has been commonly used in buildings in Turkey. Second test stage in this research included the surface temperature data which were taken from these coated and painted pavement block surfaces. These two test stages produced enough data which are plotted separately in Fig. 6.



a)



b)

Figure 6. Mean surface temperature obtained from especially prepared heat-resistive concrete pavement blocks; a) First test stage results, (mean surface temperature fluctuation on plastered pavement blocks); b) Second test stage results (mean surface temperature fluctuation on plastered and then white cool material coated & white painted concrete pavement blocks).

## 5. Conclusion

This study summarized the differences in surface temperatures obtained from different pavement blocks which were plastered by different insulation materials. Heat-resistive concrete plaster layers were applied to standard pavement blocks. In order to obtain heat-resistive plaster, 6 different heat-resistive rock aggregates were used. Main consideration was to determine which heat-resistive aggregates were suitable to obtain cool pavement surfaces.

Graphics obtained in this study present that effectiveness of heat-resistive pavement blocks on heat-island effects depends on albedo characteristics and heat insulation capacity of the prepared plastering concrete layers. It was determined that heat-resistive materials which can be used as plastering materials for concrete pavement blocks prevent heat

transferring in concrete pavement blocks. Therefore their surface temperatures were higher than the standard block's values.

Test samples which were coated with Aksaray-pumice aggregate plasters had highest mean surface temperature, (38.25 °C at 12:00 o'clock). In this stage of the tests, highest mean surface temperature of standard concrete pavement blocks was 33.80 °C. This was the value reached on the other hand at 14:00 o'clock. Differences in day time interval and mean surface temperature values can be explained by the thickness of heat-resistive plasters on pavement blocks and their heat resistance properties. It is important to point that, surface temperature of heat-resistive block decreased more rapidly when it was compared with the standard reference pavement block. This recognized point can be explained by heat storage capacity of the blocks. Heat-resistive plasters had obstructed heat radiating from sun and had declined the heat stored in concrete pavement blocks. Better results were obtained for pavement blocks' surface temperature effectiveness when the white polyester putty and white paint were used to coat surface of them. Pavement block's surface temperatures in this test group were plotted and highest value was determined for Aksaray pumice aggregate plaster. The surface temperature for this test sample was 32.50 °C at 13:00 o'clock. Standard test sample in this test group had highest surface temperature value around 30.60 °C at a time of 14:30. Surface temperature difference was 5.75 °C for these two pavement blocks for common Autumn days of Elazig city. This result shows the effectiveness of albedo characteristic of pavement blocks. It was concluded that, heat transfer resistant materials which are used in common construction sites can be used to prepare plastering layers for concrete pavement blocks. It was evaluated that heat-resistivity of pavement block surface materials and surface albedo properties are two main influencing parameters on heat-island in urban areas.

## **References**

- [1] Taleghani M., Sailor D., and Ban-Weiss GA. Micrometeorological simulations to predict the impacts of heat mitigation strategies on pedestrian thermal comfort in a

- Los Angeles neighborhood, Environmental Research Letters, Feb. 2<sup>nd</sup> 2016, 11 (2), IOP Publishing Ltd.,
- [2] Saucedo N. Cool pavements, Save our streets, LA (C.F. 13-1300-S1) Public Works Cmte Item (J), Sept. 2013; City of Los Angeles.
- [3] Inspir'ation. Los Angeles is painting its streets white to guard against climate change, Inspiration.news web site, Sept, 29<sup>th</sup> 2017.
- [4] Synnefa A., Dandou A., Santamouris M., Tombrou M., and Soulakellis N. On the Use of Cool Materials as a Heat Island Mitigation Strategy, Journal of Applied Meteorology and Climatology, Nov. 2008; 47, 2846-2856.
- [5] Akbari H. Potentials of urban heat island mitigation, Inter. Conf. of passive and low energy cooling for the built environment, Santorini, Greece, May 2005.
- [6] Santamouris M., Gaitani N., Spanou A., Saliaria M., Giannopoulou K., Vasilakopoulou K. and Kardomateas T. Using cool paving materials to improve microclimate of urban areas – Design realization and results of the flisvos project, Building and Environment, July 2012; 53, 128-136.
- [7] Santamouris M., Synnefa A. and Karlessi T. Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions, Solar Energy, Dec. 2011; 85 (12), 3085-3102.
- [8] Synnefa A., Santamouris M. and Livada I. A study of the thermal performance of reflective coatings for the urban environment, Solar Energy, 2006; 80, 68–981.
- [9] Yang J., Wang Z.H., Kaloush K.E. and Dylla H., Effect of pavement thermal properties on mitigating urban heat islands: A multi-scale modeling case study in Phoenix, Building and Environment, 2016; 108, 110-121.