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Urban Heat Island Destructive Phenomenon and Its Reduction with the Approach of Road Pavement Evaluation

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ABSTRACT: The development of urban environments and the excessive increase of urban population have increased the amount of energy consumption and as a result, the temperature of urban environments has increased. The phenomenon of increasing the temperature of cities compared to the temperature of suburbs is called the urban heat island (UHI). Energy waste, financial resource consumption, climate, and ecosystem change are the most important adverse consequences of the phenomenon of UHI. In this research, the causes of UHI, and methods to reduce this destructive phenomenon with the approach of using cool pavements, have been comprehensively studied. Research has shown that UHI can be evaluated using fixed, survey, and remote methods. One of the most effective actions is the use of reflective materials and the use of cool pavements on the roads to reduce the temperature of cities and reduce the effects of the destructive phenomenon of UHI. Results show that with the use of cool pavements, the ambient temperature and the surface temperature of the pavement surface can be reduced up to 2 ° C and 13 ° C respectively improved. The use of light-colored cement and aggregates and additives such as titanium dioxide, zinc oxide, aluminum oxide, and fly ash has been effective in reducing this phenomenon. By increasing road surface permeability, increasing the surface reflection coefficient, increasing the thermal coefficient, and decreasing the pavement thickness, the pavement surface temperature can be reduced, and the undesirable phenomenon of UHI can be prevented.

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1- Introduction

Urbanization is associated with problems such as population growth, industrialization, cost growth, social differentiation, and negative environmental impacts.[2 ,1] Global warming has attracted the attention of researchers in many countries around the world since the beginning of the 19th century. Due to the fact that more than half of the world's population lives in urban areas, it has been recognized as one of the contributing factors to urban warming[3].

Construction growth and economic activity have combined to raise the temperature of urban areas compared to suburbs. The undesirable phenomenon of urban heating islands has been caused by differences in temperature exchange in building materials and natural lands, encapsulation of sun rays between tall buildings, reduction of vegetation, low permeability of surfaces, obstacles in wind direction, and increased thermal capacity of materials [4].

Urban heat islands have changed the climate of urban areas by intensifying pollution concentration in urban environments, cloud formation, changing wind structure, increasing humidity, and changing evaporation rates [5, 6]. The phenomenon of urban heating islands depends on the climate of urban areas, and the absence of wind or low wind speed has exacerbated this undesirable phenomenon [7].

To reduce the phenomenon of urban heating islands and achieve an optimal energy plan, different methods such as changes in surface reflection, increasing sky view factor, changing the ratio of building's height to the road's width (aspect ratio), and maximizing airflow in urban areas have been used [8-10].

2- Factors of urban heat islands

Development and population growth of cities, reduction, and elimination of vegetation, and the use of materials with high heat absorption potential and low reflective power are the main factors in the formation of the undesirable phenomenon of urban heat islands[3, 11].

Human-made materials have caused this destructive phenomenon to grow due to their reflectivity and different thermal absorption properties than natural materials, less sunlight reflection, more heat absorption, and release at night[12]. Asphalt pavement used on the surface of roads and bitumen coatings on the roofs of buildings, by solar energy absorption, has caused surface heating and its surroundings [13].

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3- Destructive effects of urban heating islands phenomenon

Urban warming is an invisible phenomenon that has had irreparable consequences on human health[14]. One of the destructive effects of urban heating islands in summer is more energy consumption for cooling buildings, increasing air pollution, rising ambient temperature, and endangering community health.

Increasing the temperature of urban environments has had devastating effects on health, the economy, and the environment sectors. With increasing ambient temperature, the chemical reaction rate of pollutant particles in the atmosphere has increased, causing more air pollution and problems for pedestrians[15].

Contact of surface runoff with hot surfaces such as asphalt and bitumen coatings has increased water temperature. These hot runoffs have hurt the health and reproduction of aquatic animals by entering the rivers [16].

4- Pavement and its role in the phenomenon of urban heating islands

About 90% of urban heating is due to the use of heat-absorbent materials that tend to hold heat, and only 10% of urban warming is due to the activity of factories, vehicles, and buildings [17].

5- Cool pavement with the approach of using reflective procedures

Road construction with 40% coverage of urban structure has played an important role in urban structure and reduction of urban heating islands phenomenon[18]. One of the methods to reduce this phenomenon is the application of cool pavement.

6- Conclusions

With the development of cities, population increase, and energy consumption, the temperature of different parts of cities has changed. This temperature difference between cities and suburban temperatures has caused the destructive phenomenon of urban heat islands. Energy loss, financial resources consumption, climate change, and the ecosystem are the most important adverse consequences of this destructive phenomenon.

Using reflective surfaces, increasing sky view ratio, changing the ratio of a building's height to the road's width, increasing vegetation, and maximizing airflow in cities, this destructive phenomenon can be reduced in this regard, the use of reflective materials and the use of cool pavements on the roads have been the most important ways to reduce this destructive phenomenon. The environment temperature has been reduced up to 2°C and the surface temperature of pavement up to 13°C. using brightly colored cement and aggregates and additives such as titanium dioxide and zinc oxide have significantly reduced energy consumption and reduced the destructive effects of the urban heating islands phenomenon.

If the reflection of the sun's heat encapsulates heat and intensifies heating, pavements with solar cells can be used to absorb heat and generate electricity. Pavements with low reflection coefficients and high thermal conductivity are used to absorb heat and heat water. The performance of these procedures against traffic loads, durability and friction changes of these procedures in different weather conditions should be taken into account. Also, by increasing the permeability of the pavement, increasing the surface reflection coefficient, increasing the thermal coefficient, and reducing the thickness of the pavement, the surface temperature of the pavement can be reduced and prevent the undesirable phenomenon of urban heating islands.

References

[1] D.W. Jones, How urbanization affects energy-use in developing countries, Energy policy, 19(7) (1991) 621-630.

[2] C.I. Portela, K.G. Massi, T. Rodrigues, E. Alcântara, Impact of urban and industrial features on land surface temperature: Evidences from satellite thermal indices, Sustainable Cities and Society, 56 (2020) 102100.

[3] X.-L. Chen, H.-M. Zhao, P.-X. Li, Z.-Y. Yin, Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes, Remote sensing of environment, 104(2) (2006) 133-146.

[4] S. Grimmond, Urbanization and global environmental change: local effects of urban warming, The Geographical Journal, 173(1) (2007) 83-88.

[5] H. Taha, Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat, Energy and buildings, 25(2) (1997) 99-103.

[6] C. Sarrat, A. Lemonsu, V. Masson, D. Guédalia, Impact of urban heat island on regional atmospheric pollution, Atmospheric environment, 40(10) (2006) 1743-1758.

[7] P. Rajagopalan, K.C. Lim, E. Jamei, Urban heat island and wind flow characteristics of a tropical city, Solar Energy, 107 (2014) 159-170.

[8] J. Unger, Connection between urban heat island and sky view factor approximated by a software tool on a 3D urban database, International Journal of Environment and Pollution, 36(1-3) (2009) 59-80.

[9] M. Fossum, E.O. Ryeng, The walking speed of pedestrians on various pavement surface conditions during winter, Transportation research part D: transport and environment, 97 (2021) 102934.

[10] C. Yuan, L. Chen, Mitigating urban heat island effects in high-density cities based on sky view factor and urban morphological understanding: a study of Hong Kong, Architectural Science Review, 54(4) (2011) 305-315.

[11] C.M. Nwakaire, C.C. Onn, S.P. Yap, C.W. Yuen, P.D. Onodagu, Urban Heat Island Studies with emphasis on urban pavements: A review, Sustainable Cities and Society, 63 (2020) 102476.

[12] D.R. Streutker, A remote sensing study of the urban heat island of Houston, Texas, International Journal of Remote Sensing, 23(13) (2002) 2595-2608.

[13] M. Hulley, The urban heat island effect: Causes and potential solutions, in: Metropolitan sustainability, Elsevier, 2012, pp. 79-98.

[14] P.D. Howe, J.R. Marlon, X. Wang, A. Leiserowitz, Public perceptions of the health risks of extreme heat across US states, counties, and neighborhoods, Proceedings of the National Academy of Sciences, 116(14) (2019) 6743-6748.

[15] H. Akbari, D. Kolokotsa, Three decades of urban heat islands and mitigation technologies research, Energy and buildings, 133 (2016) 834-842.

[16] T. Susca, F. Pomponi, Heat island effects in urban life cycle assessment: Novel insights to include the effects of the urban heat island and UHI-mitigation measures in LCA for effective policy making, Journal of Industrial Ecology, 24(2) (2020) 410-423.

[17] L. Haselbach, Engineering Guide to LEED-New Construction: Sustainable Construction for Engineers, McGraw-Hill Education, 2008.

[18] N. Anting, M.F.M. Din, K. Iwao, M. Ponraj, K. Jungan, L.Y. Yong, A.J.L.M. Siang, Experimental evaluation of thermal performance of cool pavement material using waste tiles in tropical climate, Energy and Buildings, 142 (2017) 211-219.

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