5th Conference on Sustainability in Civil Engineering (CSCE'23)
Department of Civil Engineering
Capital University of Science and Technology, Islamabad Pakistan

EXPLORING THE POTENTIAL OF MOSS CONCRETE AS AN ECO-FRIENDLY SOLUTION TO MITIGATE URBAN HEAT ISLAND EFFECT

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Abstract- This paper explores the potential of moss concrete as an eco-friendly solution to mitigate the Urban Heat Island (UHI) effect. To mitigate UHI effects, various approaches can be implemented, such as energy efficiency improvement, green roof construction and utilization of high reflectivity materials. Moss concrete is a type of concrete that incorporates moss into its mixture to create a natural, eco-friendly building material. Mosses are known for their ability to retain moisture, and they can help regulate surface temperatures and reduce the UHI effect. Moss concrete is a type of biological concrete that is developed by growing moss on the surface of structures. The construction of moss concrete involves a conventional concrete layer that serves as the structural component of the building, a waterproof layer that acts as a barrier, and an outer layer of moss concrete designed to allow rainwater to penetrate and boost the growth of the organisms. Moss concrete has the potential to purify the air by absorbing excess carbon dioxide from the atmosphere along with storm-water management, improved water run-off quality and extension of roof life.

Keywords- Urban Heat Island effect, moss concrete, albedo, durability, eco-friendly, stormwater management.

1 Introduction

Urbanization has brought about numerous environmental challenges, including the Urban Heat Island (UHI) effect. UHI occurs when urban structures absorb and emit solar radiation, leading to increased temperatures in urban areas. Vegetation is essential in regulating surface temperatures and reducing the UHI effect [***1***]. Moss concrete has emerged as a potential solution to mitigate UHI due to its unique properties. A recent study was conducted to assess the impact of asphalt and concrete pavements on lowering the earth's surface temperature. The study specifically compared the albedo effects, which measure surface reflectivity, of these two pavement types in a specific application and area. The results indicated that by using concrete pavements instead of asphalt ones and increasing the average albedo, significant temperature reductions were achieved. These temperature reductions were estimated to be equivalent to removing 25-75 $kgCO_2/m^2$ [***2***]. Another research shows that the compressive strength of moss concrete as compared to the conventional concrete increases overtime [***3***]. Increasing the albedo of urban surfaces through solar reflective materials can offset temperature rise caused by global warming. Simulations showed a global cooling effect and CO2 emission reduction of 3 × 10^-15 K and 7 kg per 1 m² of surface, respectively [***4***]. This paper explores the potential of moss concrete as an eco-friendly solution to mitigate UHI and improve building materials' durability.

1.1 Moss

Moss refers to a group of non-vascular plants that belong to the division Bryophyta. These small, soft plants typically grow in dense green clumps or mats in damp or shady locations. Mosses do not have flowers or seeds and reproduce via spores. They play an important ecological role by helping to retain moisture in soil and provide habitat for insects and other small animals. Mosses are also used for various purposes, such as landscaping, gardening, and as a decorative element in crafts and art.

1.2 Urban Heat Island Effect

The Urban Heat Island (UHI) effect is a phenomenon of heat accumulation in urban areas caused by human activities and urban construction. It can have significant impacts on urban ecological systems, altering their structure and functions, and affecting urban climates, hydrology, soil properties, atmospheric environment, material and energy cycles, and residents' health. To mitigate UHI effects, various approaches can be implemented, such as energy efficiency improvement, green roof construction, utilization of high reflectivity materials, and green land cultivation. Research using remote sensing and numerical simulation methods has provided theoretical references for improving the urban ecological environment and achieving sustainable urban development [*5*]. A typical Urban heat island profile is shown in (Figure 1 [*6*]), which shows temperature is usually higher in urban areas as compared to the rural areas.

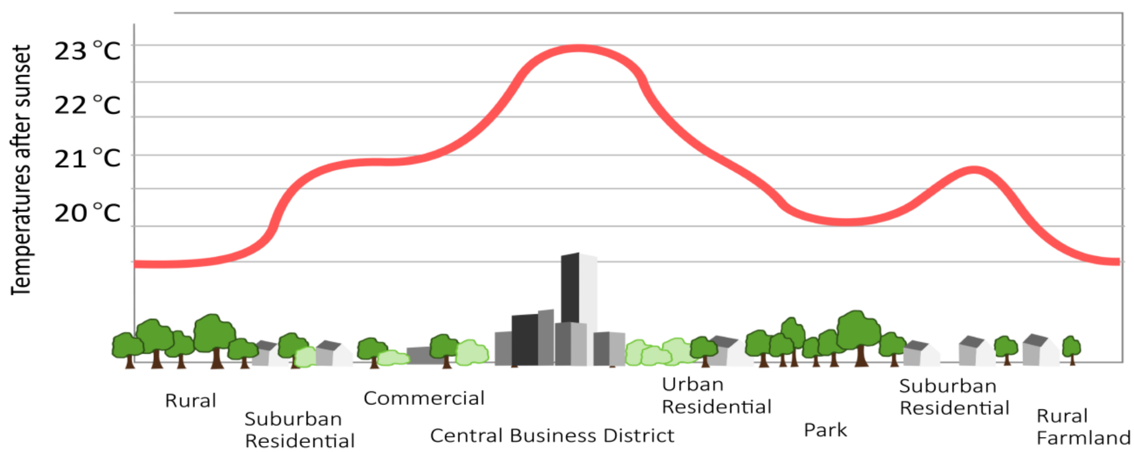

Figure 1: Urban Heat Island Profile

1.3 Green Roof Benefits

The implementation of rooftop greening is an effective option to mitigate UHI, with green roofs providing insulation and cooling the surrounding environment. Sunagoke moss has good thermal characteristics and high-speed evapotranspiration, making it a suitable afforestation plant for rooftop greening. However, industrial production of Sunagoke moss is required to meet the demand for city rooftop greening. To achieve this, plant factories are used for moss production, and a specific method of analyzing transpiration properties of Sunagoke moss has been developed to optimize the production system [*7*]. Another research suggests that sustainable ecological architecture refers to a form of building design that incorporates nature into all aspects of construction. Such buildings utilize living and non-living materials to create ecosystems or sustain existing habitats. The objective of ecological architecture is to explore the impact of ecological elements on buildings, their occupants, and the surrounding environment, highlighting the importance of balancing building design with nature [*8*].

Green roofs, which are comprised of a layer of vegetation on top of a building, offer numerous benefits including storm-water management, improved water run-off quality, improved air quality, extension of roof life, and reduction of the urban heat island effect. Extensive green roofs, which have a thin substrate layer with low-level planting such as sedum, are the preferred option for retrofitting onto existing buildings as they require minimum maintenance and are easy to install. Green roofs can also lead to building energy reduction benefits through enhanced thermal properties and insulation value. Retrofitting existing buildings with green roofs has potential for energy savings, but more research is needed to determine the extent of these benefits [*9*]. (Figure 2 [*10*]) shows a typical example of green roof.

Figure 2: Example of a typical green roof

Two types of green roofs are generally distinguished [***11***]: extensive and intensive as shown in Table 1:

Table 1: Types of Green Roofs

Extensive	**Intensive**
Low soil thickness(5-15 cm)	High soil thickness (above 15 cm)
Difficult to access	Easily accessible
Light (50-160 kg/m2)	Heavy (more than 200 kg/m2)
Can be maintained easily	Difficult to maintain
Less expensive	More expensive

1.4 Moss Concrete and How it is Made

Moss concrete, also known as "living concrete," is a type of concrete that incorporates moss into its mixture to create a natural, eco-friendly building material. Three species of moss namely Bryum apiculatum, Barbula indica, and Hyophila involuta commonly grow on the surface of damp cement-based materials [***12***].

Moss concrete is a type of biological concrete that is developed by growing moss and other organisms such as lichen and fungi on the surface of structures. The goal of this development is to help purify the air by absorbing excess carbon dioxide from the atmosphere. The construction of moss concrete involves a conventional concrete layer that serves as the structural component of the building. The next layer is a waterproof layer that acts as a barrier, separating the inner part of the building from the surface on which moss will grow. The outer layer of moss concrete is designed to allow rainwater to penetrate and boost the growth of the organisms. This layer provides water and nutrients to the moss, which is essential for its growth and survival. On the other hand, the inner portion of the concrete remains waterproofed to prevent water from seeping through to the building's interior. The waterproof layer ensures that the building's structural integrity is maintained and that the moss and other organisms do not damage the concrete structure [***13***].

2 Factors Affecting Growth of Moss in Concrete

Concrete with high porous surfaces has been found to be suitable for the growth of moss due to its ability to absorb and retain moisture. Moss typically requires a humid and moist environment to grow, and a porous surface can provide that environment by retaining water for longer periods. In addition, the rough surface of porous concrete provides a suitable substrate for the attachment and growth of moss spores. A study was conducted in 2018 in which different walling materials were compared for the growth of moss and it was found that the more the porosity of a material, more will be the growth of moss [***14***].

3 Durability of Moss Concrete

Moss concrete has been tested for its compressive strength and showed a similar or slightly lower strength compared to conventional concrete. However, the compressive strength of moss concrete was found to increase over time due to the growth of moss within the concrete, which reinforced the material [***3***].

Figure 3 shows the compressive strengths of standard and moss concrete [***3***].

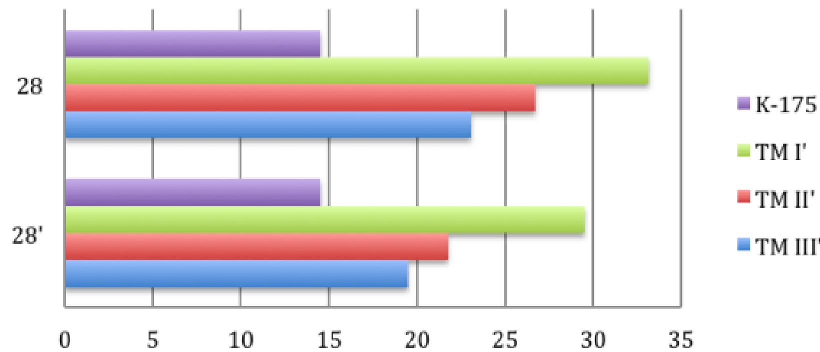

Figure 3: comparison of compressive strengths of standard concrete (K-175) vs Moss concrete (TM 1, TM 2 & TM 3)

Moss concrete offers increased resistance to acid attack and enhanced strength over time, making it a promising material for sustainable construction in urban areas. It utilizes the unique properties of moss to absorb and neutralize acidic pollutants, such as sulfur dioxide and nitrogen oxides, commonly found in urban environments. By integrating moss into concrete, it helps prevent the breakdown of calcium carbonate caused by acidic substances, maintaining the material's integrity. Additionally, as moss grows and forms a network of roots and stems within the concrete, it reinforces the structure and improves its overall strength, reducing the risk of cracking and deterioration. The combination of acid resistance and natural reinforcement makes moss concrete an ideal choice for durable and eco-friendly construction projects.

4 Protection from Rainwater and Light

Moss has been found to have a positive effect on various materials, including concrete and wood, by providing protection from rainwater and light. According to a research, when moss grows on a surface, it forms a layer of cells that can absorb and hold water, acting as a sponge. This helps to reduce the amount of water that penetrates into the material, which can cause damage over time due to freeze-thaw cycles, erosion, and other weathering effects [***15***]. In addition to its water-absorbing properties, moss also has the ability to absorb and filter light. Sunlight contains harmful ultraviolet (UV) radiation, which can cause degradation and fading of materials over time. Moss has been shown to be effective at filtering out a significant portion of UV radiation, reducing the amount of damage caused by sunlight exposure. Studies have also found that moss can help to reduce the surface temperature of materials, which can help to prevent cracking and other forms of damage caused by thermal stress. By absorbing and retaining moisture, moss can cool the surface of materials by as much as 10-20 degrees Celsius. Overall, the ability of moss to protect materials from water, light, and heat makes it a promising natural solution for sustainable and durable building materials.

5 Role of Moss Concrete in Storm-water Management and Temperature Regulation

Moss concrete has been shown to be effective in stormwater management due to the ability of moss to retain water and reduce runoff. Moss has a high water retention capacity and can absorb up to 20 times its dry weight in water. When used in concrete, it can absorb stormwater runoff, reducing the amount of water that enters the sewer system and reducing the risk of flooding. Additionally, the ability of moss to absorb pollutants in the air and water can help to improve water quality. The use of moss concrete in stormwater management can also contribute to the promotion of sustainable urban drainage systems (SUDS) and green infrastructure. A study suggests that green roofs, commonly composed of vascular plants, have been used for stormwater management. However, mosses, which are primary colonizers and have numerous soil benefits, could also be valuable components. In a study evaluating three candidate moss species, it was found that mosses had high water holding capacities and delayed and reduced runoff flows. Green roofs planted solely with Racomitrium canescens had higher stormwater retention than vascular or medium only roofs. Moss cover also ameliorated temperature fluctuations on green roofs. These results suggest that mosses have the potential to be valuable components of green roofs for stormwater management and temperature regulation [***16***].

6 Effect of Moss Concrete on Albedo

Albedo refers to the measure of the reflectivity of a surface, expressed as the ratio of the reflected radiation to the total amount of incident radiation. In simpler terms, it represents the ability of a surface to reflect sunlight back into the atmosphere. A higher albedo indicates that more sunlight is reflected, which results in less absorption of solar radiation and lower surface temperatures. Conversely, lower albedo values indicate less reflection and more absorption of solar radiation, leading to higher surface temperatures. Green roofs have a high albedo, ranging from 0.7 to 0.85, which is significantly higher than conventional roofing materials. The high albedo of green roofs is due to the presence of vegetation, which reflects a large portion of the incoming solar radiation. This reduces the amount of heat absorbed by urban surfaces, lowering surface temperature and mitigating the UHI effect. The presence of vegetation also provides shading and evapotranspiration, which further helps to cool the surrounding environment [***17***].

Following chart shows solar reflectance (albedo) of different roofing materials [***17***].

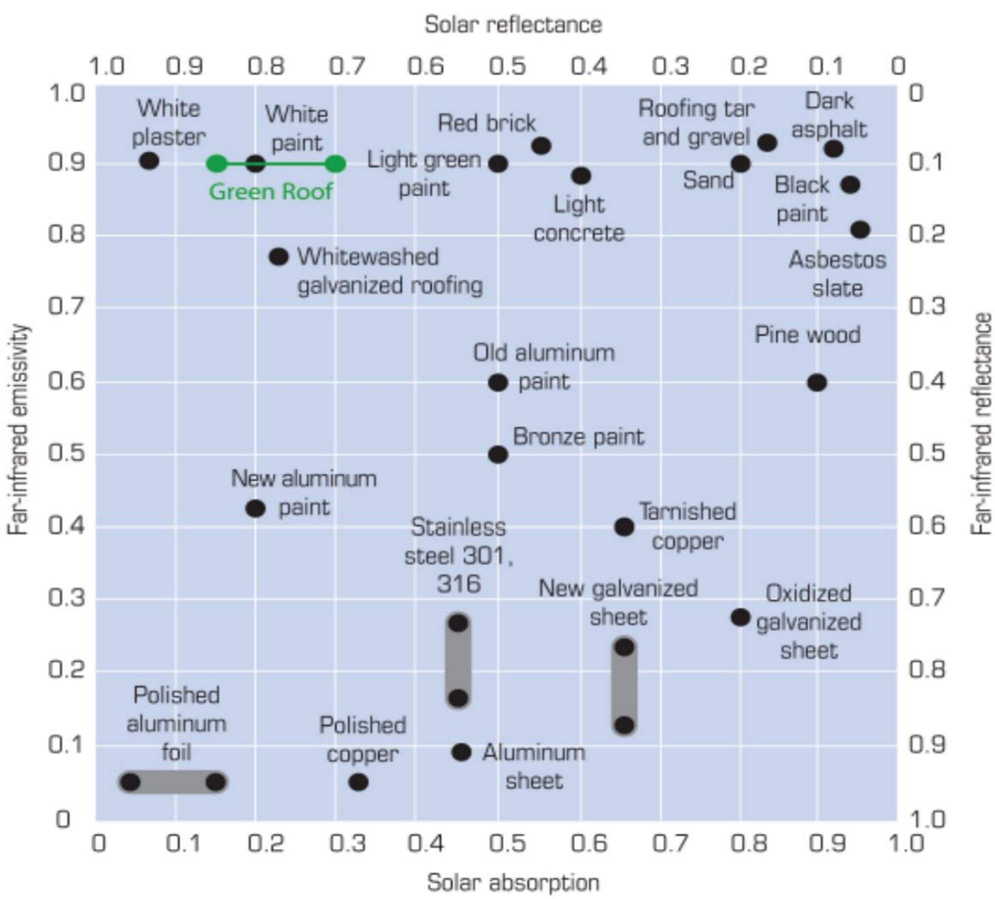

Figure 4: Data on solar reflectivity (horizontal axis) and infra-red emissivity (vertical axis) for a number of common building materials.

A recent study investigated the potential of solar reflective urban surfaces, such as white rooftops and light-colored pavements, to raise the albedo of urban areas by approximately 0.1. The aim was to assess their impact on mitigating global warming by reducing atmospheric temperature. Using a spatially explicit global climate model, long-term simulations were conducted to examine the effects of increased urban surface albedos over decades to centuries. The simulations involved increasing the albedo of all land areas within specific latitudinal ranges. The findings revealed that for each 1 m^2 of surface with a 0.01 albedo increase, there was a long-term global cooling effect of approximately 3 × 10^-15 K. This cooling effect is equivalent to reducing CO2 emissions by around 7 kg based on recent estimates. Additional simulations focused on increasing the albedo of urban areas alone, considering different spatial extents. These simulations showed global cooling ranging from 0.01 to 0.07 K, which corresponds to a reduction of CO2 emissions by 25-150 billion tonnes in CO2 equivalent [***4***]. Moss concrete has a high potential to improve the albedo effect due to the presence of moss, which has a high albedo. The pre-planned geometry in the panels of moss concrete provides a suitable environment for moss to grow, as it allows for adequate moisture retention and drainage. The growth of moss on the surface of the concrete helps to increase its albedo, which in turn leads to lower surface temperatures [***18***]. Another study found that, at minimum, green roofs have a 200% increase in albedo over conventional roofs [***19***]. A minimum albedo increase of 200% provides a huge potential for decreased absorption of the sun's radiation, and thus decreased warming effects on the surrounding air

7 Disadvantages of Moss Concrete

Mosses produce oxalic acid as part of their metabolic processes, and this acid can contribute to the erosion of concrete. Oxalic acid can react with calcium ions in the concrete to form calcium oxalate crystals, which take up more space than the original calcium ions, leading to the expansion of the concrete. This expansion can cause stress on the concrete, leading to cracking, spalling, and other forms of damage. In addition, the moisture retention properties of moss can lead to increased water retention in the concrete, which can further contribute to erosion and damage over time. However, some researchers are studying ways to mitigate these effects by altering the composition of the concrete or applying coatings to protect against erosion. [***15***].

8 Practical Applications of Moss Concrete

The practical application of moss concrete involves utilizing moss as an integral part of the concrete mixture to enhance its properties and provide additional benefits. This innovative approach has several practical applications in construction and landscaping:

i. Green Walls and Facades: Moss concrete can be used to create living green walls and facades, where the concrete is specifically designed to support the growth of moss. These vertical gardens offer numerous advantages, including improved air quality, thermal insulation, and visual appeal. The moss acts as a natural filter, removing pollutants from the air and reducing noise levels.

ii. Pavements and Walkways: Moss concrete can be used in pavements and walkways, providing a visually appealing and eco-friendly alternative to traditional concrete or asphalt surfaces. The moss in the concrete mixture not only adds a touch of greenery but also helps to reduce heat island effects by absorbing and dissipating heat.

iii. Noise Barriers and Sound Walls: Moss concrete can be incorporated into noise barriers and sound walls along highways, railways, and other noisy areas. The moss acts as a sound-absorbing material, reducing the propagation of noise and creating a more peaceful environment.

iv. Ecological Restoration: Moss concrete can play a role in ecological restoration projects by providing a sustainable substrate for moss growth in areas that require vegetation cover. It can be used in erosion control measures, slope stabilization, and habitat creation.

v. Urban Landscaping: Moss concrete can be used in various urban landscaping projects, such as parks, gardens, and public spaces. It adds a touch of greenery, improves aesthetics, and contributes to the overall environmental sustainability of the urban environment.

The practical application of moss concrete offers an innovative and eco-friendly approach to construction and landscaping, providing numerous benefits such as improved air quality, thermal insulation, noise reduction, and ecological restoration. It showcases the potential for integrating natural elements into the built environment, promoting sustainability and creating greener and more harmonious spaces.

9 Conclusions

In conclusion, moss concrete has emerged as an eco-friendly solution to mitigate the Urban Heat Island (UHI) effect and improve building materials' durability. Mosses, known for their ability to retain moisture, can help regulate surface temperatures and reduce the UHI effect. Moss concrete incorporates moss into its mixture, creating a natural building material that offers several advantages. Firstly, moss concrete contributes to stormwater management by absorbing and retaining water, reducing runoff and the risk of flooding. Moss has a high water retention capacity and can absorb up to 20 times its dry weight in water. By using moss concrete in construction, the amount of water entering the sewer system is decreased, improving water quality and promoting sustainable urban drainage systems (SUDS).

Secondly, moss concrete offers increased durability over time. While its initial compressive strength may be similar to or slightly lower than conventional concrete, the growth of moss within the concrete reinforces the material, enhancing its compressive strength. Moss concrete also demonstrates resistance to acid attack, preventing the breakdown of calcium carbonate and maintaining its integrity. Furthermore, moss concrete has a positive impact on temperature regulation and the reduction of the UHI effect. Moss has a high albedo, reflecting a significant portion of incoming solar radiation. By increasing the albedo of urban surfaces, moss concrete helps to lower surface temperatures and mitigate the impact of global warming. The presence of vegetation in green roofs, including moss, also provides shading and evapotranspiration, further contributing to cooling the surrounding environment. However, moss concrete does have some disadvantages. Mosses produce oxalic acid, which can contribute to the erosion of concrete. Researchers are exploring ways to mitigate these effects by altering the concrete composition or applying protective coatings. In summary, moss concrete offers an eco-friendly solution to mitigate the UHI effect and improve building materials' durability. By incorporating moss into concrete, it provides benefits such as stormwater management, enhanced durability, temperature regulation, and increased albedo. While further research is needed to address potential challenges, moss concrete shows great potential as a sustainable and effective solution for urban environments.

Acknowledgment

The authors would like to thank every person/department who helped thorough out the research work, particularly Engr. Sohaib Nazar. The careful review and constructive suggestions by the anonymous reviewers are also gratefully acknowledged.

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