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كلية الفنون الجميلة - جامعة المنصورة

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المؤتمر العلمي الدولي الأول

التكامل بين الإبداع والتكنولوجيا والإبتكار

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تأثير الأسطح الخضراء على الأداء الحراري للمبنى في المناخ المحلي لمدينة الرياض

Impact of Green Roof on Thermal Performance of the Building in the Local Climate of Riyadh City

Case Study: (Towers Square Building – Saudi Arabia – Riyadh)

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Abstract

This study explores the role of green roofs in enhancing the thermal performance of buildings under the harsh climatic conditions of Riyadh, Saudi Arabia. Urbanization has significantly reduced green spaces, intensifying the urban heat island effect. Through the application of an intensive modular green roof system on Towers Square, thermal data were analyzed, showing marked improvements in thermal comfort and reduced energy consumption. The findings advocate for the widespread adoption of green roofs to promote sustainable urban development.

Key Words:

Energy Conservation, Green Roofs, Riyadh, Thermal Performance, Urban Heat Island

1. Introduction

Riyadh's rapid urban expansion has led to significant environmental degradation, notably a reduction in green spaces, contributing to the urban heat island effect. This phenomenon describes how urban areas become significantly warmer than surrounding rural areas. This study aims to evaluate the potential of green roofs to enhance building thermal performance and reduce energy consumption. The research hypothesis suggests a general unawareness of the environmental benefits of green roofs among local communities. A combined theoretical and field study methodology was adopted, integrating case analysis and simulation techniques.

2. Theoretical Framework

2.1 Concept of Green Roofs

Green roofs involve the installation of vegetative layers atop building roofs, serving ecological, aesthetic, and thermal purposes.

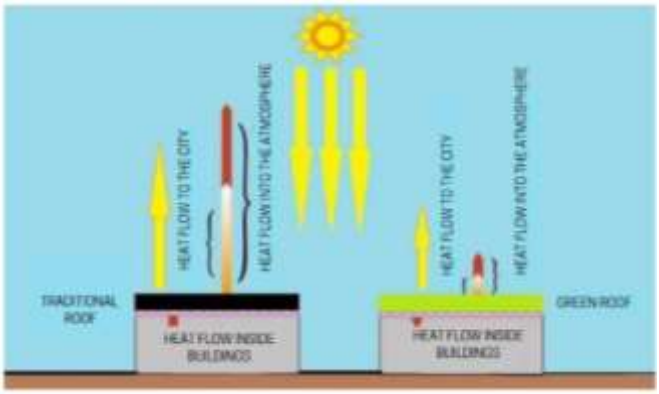
2.2 Types of Green Roofs

Extensive Green Roofs: Lightweight systems with shallow soil depth, low maintenance, and limited plant diversity.
Intensive Green Roofs: Heavier systems capable of supporting diverse plant life and recreational spaces, requiring more maintenance.

2.3 Advantages of Green Roofs

Green roofs provide substantial environmental benefits including thermal insulation, stormwater management, and noise reduction. Socially, they enhance urban aesthetics and contribute to mental health. Economically, they reduce energy costs and extend roof lifespans.

	Advantage	**Advantage Type**
1	Environmental	Climatic: • Controls the temperature of the building as it heats up in the winter and cools down in the summer (thermal insulator). • Reduces the quantity of rainwater that seeps into the ground, which functions as a sponge, absorbing water and benefiting plants. • Incentives for the adoption of ecologically friendly materials (promoting sustainability) • Reduce noise, particularly in cities.
2	Social	Aesthetic: • Adding aesthetic value to the building. • Giving the building a distinctive look. • Achieving biodiversity and wildlife.
		Healthy: • Reduces pollution by purifying the air. • Improves water quality by keeping pollutants out of the water and therefore lowering sickness. • Provides clean air in cities. • Reduces stress. • The presence of green spaces, particularly in hospitals, reduces heart rate and blood pressure.
		Entertainment: • Instead of ignoring areas, make use of them for entertainment. • Festivals can be held in these areas. • Sitting in these spaces allows people to rest and unwind. • Increasing the number of conveniently accessible green spaces in all areas.
3	Economic	• Excellent sound insulation and noise reduction, particularly in high-traffic regions and near airports.



		• The ability to direct rainwater. • The ability to supply agricultural produce is required by the building's personnel. • The utilization of recycled materials thereby decreases expenses while saving on garbage transportation costs. • Building insulation saves money on heating and cooling bills. • Increasing the structure's lifespan (building roof).

Table (1) Shows the advantages and disadvantages of green roofs on buildings.

Fig (1) Green roofs' impact on building thermal performance and preservation.

https://doi.org/10.1029/2003JB002715

Decreasing the demand for air conditioners and, as a result, conserving energy.

Green building surfaces, through plant root activities, can help prevent heat loss from buildings during the winter.

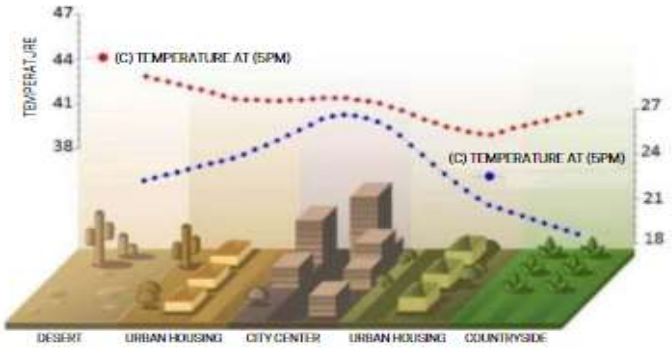


Fig (2) The thermal island, as well as the temperature difference between the city and its outskirts

https://www.researchgate.net/publication/372688454_A_study_on_the_relationship_between_urban_heat_island_phenomena_and_land_use_a_case_study_of_Chiang_Rai_Municipality_Thailand?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6Il9kaXJlY3QiLCJwYWdlIjoiX2RpcmVjdCJ9fQ

In major cities, the temperature difference between downtown and the rural suburbs is 5 °C.

Terrestrial green spaces in hot, arid environments reduce temperature by 3 °C when increased by 40%. Roof space accounts for a sizable portion of the urban surface.

Fig (3) The ability of green roofs to retain rainfall when compared to other types of roofs

https://www.researchgate.net/publication/262726604_Investment_Methods_in_Sustainable_Water_Resource_Management_using_SAW_Method

The green ceilings of the buildings function in such a way that they influence the rain drainage

system and lessen the possibility of local flooding.

Fig (4) The impact and aesthetic utility of green ceilings in buildings

https://greeninstitute.ng/greenglossary-blog/2023/7/11/green-cities

2.4 Green Roof Types:

Green roofs are categorized into two types based on the thickness of the soil, the purpose of use, and the amount of plant diversity they support:

2.4.1 Extensive Green Roof

In addition to the minimum growing medium, this type incorporates one or two types of plants.

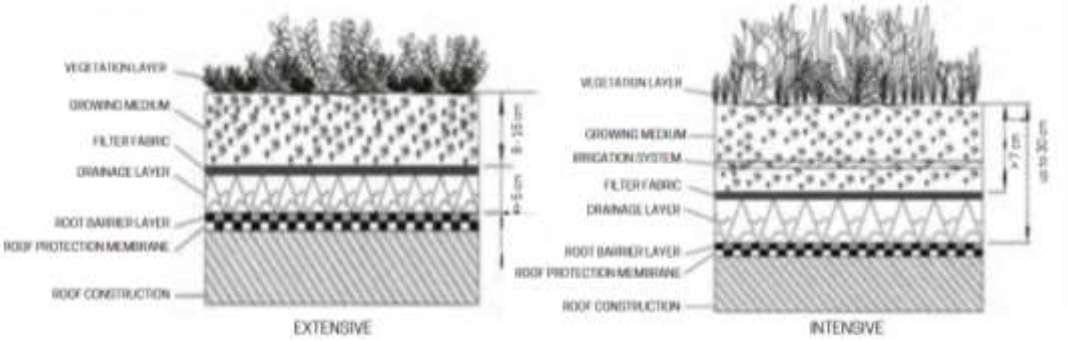


Fig (5) Green types

https://depts.washington.edu/open2100/pdf/2_OpenSpaceTypes/Open_Space_Types/green_structures.pdf

2.4.2 Intensive Green Roof

Also known as a raised bed garden or roof garden, typically has a variety of plant types organized and prepared as a park.

	Extensive	**Intensive**
Depth of Use	Less than 15cm	More than 15cm
Accessibility	Often inaccessible	Usually, accessible
Fully Saturated Weight	169-72 kg/m³	967-290 kg/m³
Plant Diversity	Low	High
Cost	Low	High
Maintenance	Low	High

Table (2) shows the difference between extensive and intensive green roofs.(The researcher)

Intensive Green Roof	**Extensive Green Roof**
Deep soil, irrigation system, more favorable conditions for plants.	Thin soil, little or no irrigation, stressful conditions for plant.
Pros: Good insulation properties. Greater diversity of plants and habitats. Can simulate a wildlife garden on the ground. Can be made very attractive. Often visually accessible. Diverse utilization of roof (i.e., for growing food, recreation, as open space) It makes better use of energy. It can store rainwater. Maintains the roofing layers' components It is more effective at insulating heat and sound than the extensive type.	Pros: Lightweight. Suitable for large areas. Suitable for roofs with 0-30 degrees slope. Low maintenance. Often no need for irrigation and drainage system (according to the European climate). Often suited for retrofitting projects. Can leave vegetation top develop spontaneously. Relatively inexpensive. If you wish to change the type of soil or plant, it is simple to replace.

Cons: Greater weight loading on roof. More complex systems and expertise required. Higher cost. Needs for irrigation and drainage systems, hence greater need for energy, water, materials, etc.	Cons: Inadequate energy efficiency and rainwater retention. More limited choice of plants. Unattractive to some, especially in winter. Usually, no access for recreation or other uses.

Table (3) shows advantages and disadvantages of extensive and intensive green roofs. (The researcher)

Some argue that there is a third type between the two fundamental types: semi-intensive. It is in the middle and has requirements and characteristics regarding weight, cost, maintenance, and so on. This third type bridges the enormous gap between the two basic types (extensive and intensive), although it is classified as intensive because its features allow for general uses.

2.4.3 Green Roof Installation Techniques

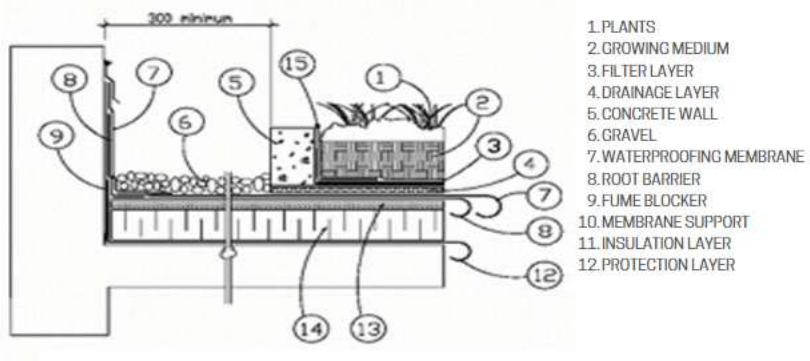
Among the various types of green roofs for buildings, various technologies or procedures can be utilized to install these roofs, with the following being the most common:

1) Complete system **2) Modular system** **3) pre-cultivated blankets**

1- Complete System

The complete system is so named because it is part of the building and is planned before with the building's design, but the weights and details that go into the development of the green roof are calculated.

This type is added to the roof during or after construction and comprises all of the key



components of the green roof, beginning with the roof layer and ending with the plants, as shown in Figure 6.

Fig (6): Complete roofing system, which contains various and different layers**.**

https://www.researchgate.net/publication/303458425_The_FUTURE_BELONGS_TO_THOSE_WHO_BELIEVE_IN_THE_BEAUTY_OF_THEIR_DREAMS

This roofing system includes a variety of layers for the building of the green roof, such as membranes, growth media, vegetation, and others. As a result, this system adds to the increased loads and weights of the structure or facility, resulting in a higher construction cost. Furthermore, because this system is a component of the structure, it was difficult to replace and change its shape because it contains several complex layers.

2- Modular System

This system is simpler to build and implement than the complete system because plants are typically grown in pots (of varying sizes and heights depending on market demand), and these pots contain pipes to drain water and are made of materials that provide insulation and protection of the roof outside the site, and when fully planted, it is moved and placed on the roof (the green roof to be built on) to serve as a substitute to the traditional roof. This system's depth and kind of soil are both adjustable, however, deep soil layers are not uncommon. Typically, a modular roofing system has a depth range of 7.5 cm to 30 cm. Figure 7 shows a modular roofing system.

Fig (7): The modular roofing system

https://www.greenroofs.com/projects/abc-supply-company-headquarters/

3- Pre-cultivated Blankets

This system is like the modular system in that it is grown outside of the site. The depth of the

growing medium and the diversity of plants are the key differences between it and the modular system. This technology is typically comprised of interlocking folding tiles that may be simply installed on any surface. These plant covers are quite thin and do not provide much flexibility in terms of growth medium or plant selection. Because of the little depth of the growing medium and the whole system, it is exceedingly light. Figure 8 shows the several levels of this type.

Fig(8): The detailed layers of the pre-cultivated blankets system

https://www.researchgate.net/publication/309111884_Performance_of_an_Ultraviolet_Mutagenetic_Polyphosphate-

	Pre-cultivated Blankets	Modular System	Complete System
Maintenance /Repair	Easy	Easy	Difficult
Installation	Quick and easy	Quick and easy	More involved installation
System	Pre-planted	Pre-planted	Layer combinations
Weight	Low	Moderate	High to moderate
Flexibility	Low	Moderate	High

Accumulating_Bacterium_PZ2_and_Its_Application_for_Wastewater_Treatment_in_a_Newly_Designed_Constructed_Wetland

Table (4): Comparison of the available systems and technologies for installing green roofs.

(The researcher)

According to the foregoing, and after studying and clarifying the techniques for constructing green roofs, these available techniques can provide great flexibility in the mechanism of

establishing and implementing different types of green roofs, depending on the type to be implemented and for whatever purpose; these techniques also provided multiple options for implementation in terms of weight differences, plant diversity, and others.

3. Case Study: Towers Square Building

3.1 The Jean Vollum Natural Capital Center

Country: United States of America

Reason for selection: Its diverse climate and the presence of cold climate regions, which provides an opportunity to study the impact of natural factors on architectural design and sustainability.

A collection of renters' homes. The building is located at 721 Portland Avenue 9th NW, Portland, Oregon. The building was started in 1895 and finished in 1896. It was refurbished in 1999, and it reopened in 2001 following reconstruction and restoration, as well as the installation of a third floor, with a floor space of 70,000 square feet (6,500 m 2). Figure 9 depicts the full structure.

Fig (9): The Jean Vollum Natural Capital Center

https://en.wikipedia.org/wiki/Natural_Capital_Center

The makeover included the installation or construction of a green roof, which was built to bring comfort to the residents because it is a favorite location for relaxation.

- A large-scale green roof with a surface area of 2000 m2.
- It is estimated that it costs $75,000 more to build than a traditional roof.
- It is solely accessible to building residents and maintenance personnel.

This green roof was created with a lightweight system that includes a copper membrane that acts as a root barrier, a drainage layer for excess water, and 5–10 cm of soil (growth medium) filled with local flowers and herbs. The drainage layer is made of white polyester and contains bundles of hydrogen crystals that swell to hold water when it rains. The bundles expand with the water, filling the tiny valleys between the peaks that serve as drainage outlets. Many of the sustainable project components are included, such as rainwater filtering through the green roof. Furthermore, more than 80% of the site's surface drainage is used to irrigate green areas.

Recycled construction debris was also employed in the project, and materials that emit clean energy (solar cells) were placed and utilized, as shown in Figure 10, and the project was planned to provide the building residents with maximum access to natural light and vistas. The USGBC awarded the project a LEED certification.

Based on the preceding, we can conclude that the green roof installed here on an old historical building in the city is the type of extensive green roof that is simple and does not add excessive loads and weights to the building. As a result, the type depicted in this structure can be used locally in Riyadh. This is one of the benefits of this structure, since its success rate is likely to be high, particularly in residential buildings that were not constructed in advance to compute additional loads. This style will be suitable in new and old residential buildings in Riyadh due to its simplicity and ease of construction, as well as its simple loads.

Fig (10): Using solar cells with green roof after building renovation.

https://www.publicdomainpictures.net/en/view-image.php?image=116412&picture=generator-control-panel

3.2 The Fairmont Waterfront Hotel Herb Garden

Country: Vancouver, British Columbia, Canada..

Reason for selection: The hotel's choice to grow an herb garden in a cooler (rather than hot & dry) climate highlights adaptation to the local environment and promotes sustainability, aligning with Vancouver's green identity.

The green roof was constructed on top of the restaurant's roof. It is a form of intensive green roof with a 200 square meter size. This saves the business $25,000–20,000 per year because it contains the plants used in the restaurant, as illustrated in (Figure 11). This is the result of not purchasing vegetable crops from local markets because they are available on the green roof.

Fig (11): The Fairmont Hotel in Vancouver

https://www.walmart.ca/en/ip/mvexperiences-vancouver-bc-2-night-getaway-package-at-the-fairmont-waterfront-vancouver/6000195374632

This green roof is also available as a green open space used by hotel guests and is properly cared for and maintained. The green roof's annual maintenance expenditure is projected to be around $0.16. This roof is made up of a concrete slab with a homogenous membrane of two layers of

waterproofing material, 30 cm of foam insulation, and a piece of fabric for drainage, as well as rocks and soil, and is designed to support the weight of soil and plants.

Fig (12): Use of vegetable crops on the green roof of the hotel

https://meetingsmags.com/national/ntl_planning/moving-forward-staying-local/

Providing vegetable crops for the restaurant and using it as a place for relaxation and enjoyment were among the benefits acquired in this hotel because of the installation of the green roof. Special balconies were opened, and they became more expensive than the other rooms. (Figure 13.)

Fig (13): The view from the hotel on the roof of the restaurant

https://aiph.org/wp-content/uploads/2021/01/11_Bill-Hardy.pdf

From the foregoing, it is obvious that in this project, an intensive green roof with large weights and loads was utilized, as this kind necessitates pre-calculating the loads during the design phase.

This project also supports research to assess the extent to which such strategies can be used to structures in Riyadh.

4. Economic and Social Criteria Affecting the Design of Green Roofs

A - Economic Criteria

There are several options for creating a green roof when estimating the original budget and cost of construction. All expenses and benefits of a green roof must be estimated separately for each project or model. Many factors influence the necessary capital to establish and maintain green roofs, including the development of an existing roof versus new construction, access to the green roof and maintenance requirements, market location, transportation cost, and resource abundance.

Green roofs in new buildings typically have a greater upfront capital cost than traditional roofs, although this difference is attributable to the building's economic life cycle. Cost factors are one part of the project that the design team can influence by creating a future budget that shows the owners how to recoup the cost difference when deciding to create a green roof over the life of the building.

B - Social Criteria

There is no proof of residents' need for green areas, recreational services, and open spaces stronger than their turnout on holidays to open spaces, even if it is a narrow island on either side of a road, despite the danger of car and vehicle movement on their lives and the lives of their children. Despite the noise, it is green and devoid of pollutants generated by car traffic.

Because of the psychological pressures that the citizen is subjected to as a result of the various current burdens, as well as the increase in rates of overcrowding and housing units, the citizen, regardless of his social, cultural, and material level, has become more in need of recreational services.

When attempting to create open spaces on the roofs of buildings and houses, the mixed community encounters various social challenges that limit the experiment's implementation, including:

- The population's social, cultural, and physical status.
- Priorities and some uses vie for prominence on the surface.
- Social and familial cohesion among building occupants; the higher this cohesion, the greater the likelihood of constructing and maintaining these gardens.
- Awareness and culture of agriculture.
- Being a part of the community and being eager to help solve its problems.

5. Case Study: Towers Square Building

5.1 Site Description

Following differentiation, the analytical criteria were used for **Towers Square** to reach design criteria suitable for Riyadh's climatic environment. The building and the general area were studied, and the harmful treatments utilized were clarified before the green roof was installed on the building's rooftops to reduce energy consumption and increase thermal performance inside the structure.

5.2 Analytical Criteria

The study analyzed building orientation, construction materials, rooftop accessibility, and overall energy performance.

Location	Examine the building's location and the time of day when it is exposed to solar radiation.
Location Natural Considerations	Investigate the site's urban planning and design foundations, as well as the ideal locations for adding green spaces to reduce heat load.
Climatic Factors	Wind: Because wind is one of the climatic elements that influences roof design. Building orientation: a study of the building's

	orientation in relation to the predominant wind direction and periods of solar radiation exposure. Block formation: the effect of the wind rises as the height of the block increases. Rain: the seasons and quantity of rain have a direct impact on the design of the green roof.
Construction Considerations	Understanding the extent and suitability of the building materials utilized aids in understanding the extent and suitability for the environment. Understanding the type of soil utilized, materials, and floors aids in determining the extent to which they affect the load of the building.
Roof Accessibility	There must be access to the location for maintenance and the addition of any materials, as well as access to the roof.
The Economic Importance of the Building	The extent to which the building fulfills its economic function is determined by its thermal performance and energy usage.

Table(5) showing the analysis criteria for the study.

5.2.1 Location

- The building is situated in an open-plan region with a reduced amount of natural and water components such as trees and fountains, and it is flanked by large streets.
- Throughout the day, the building is directly exposed to solar radiation.

5.2.2 Location Natural Considerations

To minimize the temperature radiated around the structure, the following elements have been used:

- Fountains were employed instead of fixed pools of water to chill and cool the air surrounding the building to avoid reflections of the sun's rays.

- Natural components were utilized and placed from the south to operate as a barrier in the summer, reducing the entry of the southern breezes laden with soil and heat.
- Natural stones and granite were selected to pave the corridors because they collect heat during the day and slowly release it at night.
- The rooftops of the building's commercial portion were covered with artificial grass, which served only as a decorative element.

5.2.3 Climatic Factors

The wind consists of the following elements:

- Building orientation: the blocks were oriented to receive the least amount of solar radiation by lowering the area of the ribs in the eastern and western facades and orienting the blocks north and south.
- The creation of blocks is distinguished by the fact that each of them remains the same, and this is a beneficial trait since it works to reduce the heat that enters the blocks.
- Rain: the seasons and amount of rain are among the factors influencing the design of the green roof. It is clear that they do not use this in their design or profit from it in their processes.

5.2.4 Construction Considerations

Loads and building materials:

- A double wall of red bricks was utilized, with a hollow between them that allows air to circulate between them, lowering temperatures. Because of the sluggish heat transfer through reinforced concrete, concrete structures were used in building.
- Glass curtain walls were also utilized in conjunction with treatments that reduced the amount of heat within the building.

5.2.5 Roof Accessibility

The building's roof is accessible, although it is not open to the public. It is solely for building employees. It is accessible through private elevators. It has central cooling devices but is underutilized.

5.2.6 The Economic Importance of the Building

We can observe that the building's economic role in terms of thermal performance and energy consumption is weak, as we can see from the reliance on mechanical ventilation and the use of glass areas on the facades, which increases the heat load and hence the energy consumption for cooling. Additionally, the ceiling was not utilized optimally.

Through the case study analytics, we notice the following.

- Failure to include natural and water components in a considerable proportion of the building, despite their significant function in decreasing solar radiation and increasing space availability.
- Using big glass surface areas, even if they are treated, increases the heat load, requiring a considerable amount of energy to remove that heat.
- Most of the spaces inside the building relied heavily on artificial ventilation and lighting, resulting in significant energy usage.

5.3 Green Roof Application

An intensive modular green roof system was applied. Temperature measurements indicated significant cooling effects, both externally and internally.

The proposed skyscraper (Towers Square) was investigated and compared between the two situations by utilizing green and traditional roofs and applying the vocabulary extracted from the theoretical framework, which are as follows:

- A green roof was used in the practical trial.
- The green roof utilized was of the intensive
- The modular system of green roof technology.
- The Chamomile and Good Morning flowers, which is utilized on the green roof, is distinguished by its high temperature tolerance and rapid development in high temperatures, and it is ideal for the local environment.

Figure (14) shows a proposal to apply the green roof to the entrance ceiling of Towers Square.

(The researcher)

The experiment involves putting the green roof to the rooftops of The Towers Square building, as shown in the previous figure (16) and comparing the temperature to that of the building's traditional "original" roof.

Also, measuring the temperature of each of the two roofs and comparing it to the temperature of the yard surrounding the building after planting the same type of plant on it, and then applying and accessing the extracted results to determine the extent of the green roofs' ability to reduce the temperature in Riyadh City. (Figure 16).

5.4 Measurement Techniques

The temperatures and relative humidity were measured for several models of green roofs, traditional roofs, and ground surfaces outside the building, and the benefits and characteristics of green roofs were clarified in advance.

Where they were measured, I created a model of The Towers Square building using the simulation application Ecotect, and measurements were taken for the roofs in their usual

condition with the concrete roof and in the scenario of putting the green roof.

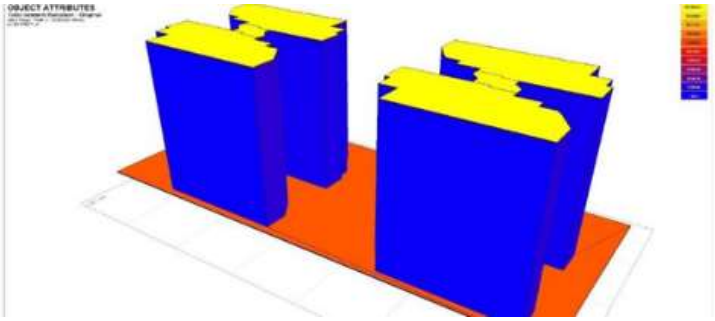
Fig (15) This image depicts the appearance of The Towers Square following the green roof proposal.

(The researcher)

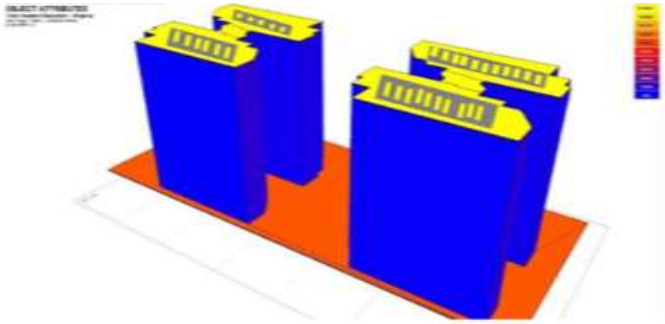
Period of measurement

The model's temperature was recorded on various days between June 6 and July 7.

Graph showing temperature measurements.



Total radiation on the building



Many investigations and research have found that the surface of the vegetation cover ("grass") creates shade on the roof surface. As a result, a single panel surface was constructed above the

roof, blocking 40% of the sun's rays and giving shade to provide measures and outcomes comparable to the green roof.

5.5 Measurement Results

Measurements were acquired for various heights, as well as measurements from the inside of the green and traditional roofs. The measurements were taken on specified days in the months of June 6 and July 7. The temperature and relative humidity of the various roofs were measured, and it was discovered, as indicated in the data, that there was a significant difference between the temperatures of the green roof and the traditional one, both inside and outside.

5.5.1 A Comparison of the Green Roof with the Traditional Roof

The temperature results of the green roof and the traditional roof were compared using two criteria:

- Outside the building (outside the model, outside temperature and relative humidity measurements.)
- Inside the building (inside the model, measure the indoor temperature and relative humidity.)

Measurements	**Green Roof**	**Traditional** Roof
Interior	The highest temperature is 3.37 degrees Celsius.	The highest temperature is 7.49 degrees Celsius.
Exterior	The highest temperature is 5.35 degrees Celsius. Minimum 32 degrees Celsius.	The highest temperature is 9.43 degrees Celsius. Minimum 6.36 degrees Celsius.

Table (6): Shows the difference in temperature measurements in the experiment.

(The researcher)

A: Measurements were Collected from the Exterior

It was discovered that the green roof had a temperature differential of less than 11 degrees Celsius in most cases and days of July and August, and that the greatest temperature of the green roof was 3.37 degrees Celsius. While the difference in temperatures between the highest and lowest value in the traditional roof exceeds more than 5.21 degrees Celsius on different days. In addition, the traditional roof's peak temperature was 7.49 degrees Celsius. At the greatest temperature observed, the difference between the traditional and green roofs was discovered to be 12 degrees Celsius.

The findings of the external measures demonstrate the importance of the green roof in minimizing the environmental effects of sunlight reflection and thus its impact on the thermal urban environment when compared to the traditional roof. As shown by the results, there is an additional economic benefit in addition to the indicated environmental benefit, which is to extend the life of the building's roof. Because of the small difference between the highest and lowest values of temperatures recorded during the day for the green roof, which leads to the lack of expansion and contraction that occurs on the roof due to the large difference between the highest and lowest value, the green roof costs more than the traditional roof.

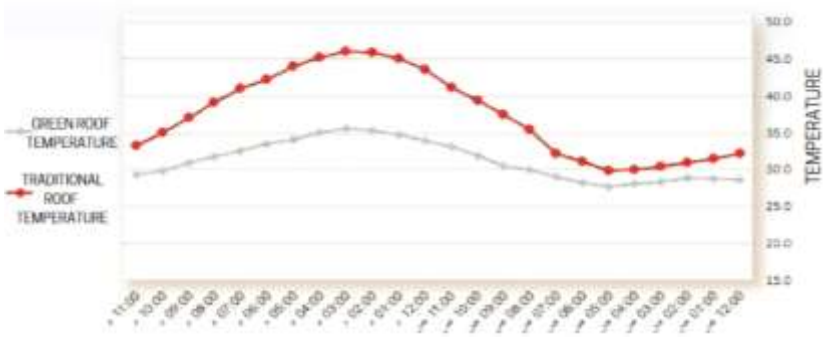


Fig (16): Shows the difference between the external temperatures between the green roof and the traditional roof.(The researcher)

B: Internal Measurements

The difference between the highest temperature reached more than 7 degrees Celsius at the peak time where it was the highest recorded temperature was discovered through the recorded results of the temperatures between the surface of the green roof from the inside and the temperatures of

the traditional roof surface from the inside (as shown in the table). The results also revealed that the green roof reached 5.35 degrees Celsius from the inside, and the lowest degree reached was 32 degrees Celsius, while the traditional roof reached 9.43 degrees Celsius from the inside, and the lowest degree reached was 6.36 degrees Celsius.

Furthermore, the average daily difference in temperatures recorded for the green roof from the inside was 1.3 degrees Celsius, whereas the daily difference in temperatures recorded for the traditional roof from the inside for one day was more than 6 degrees Celsius, as shown in the figure (17), which depicts the difference in temperatures between the green roof and the traditional roof from the inside.

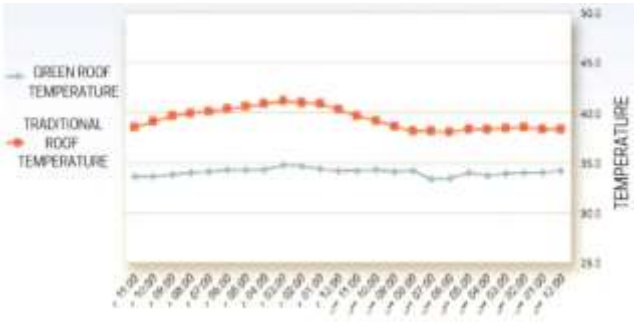


Fig (17): Shows the differences between the temperatures between the green roof and the traditional roof from the inside.(The researcher)

By examining the results, we discovered that green roofs could reduce building temperatures and cooling rates when compared to traditional roofs, resulting in reduced energy consumption and the use of cooling devices during hot summer months. As a result, it leads to another economic gain from reducing the energy consumption required for cooling, as well as a health benefit from not contributing to air pollution because of the cooling devices utilized.

5.6 Discussion

After analyzing the case study of (The Towers Square) in the last chapter, and see the results, a set of conclusions and suggestions connected to the essence and aims of the research were obtained, validating the research hypotheses.

- Roof cultivation and water recycling is one of the most important modern technologies utilized throughout the world to reduce energy consumption and soften the atmosphere inside and outside of buildings.
- In hot desert settings, design is influenced by climatic variables, particularly sunlight.
- The impact of the sun can be lessened by developing water bodies and planting green spaces around and on top of buildings.
- Green roof technology has the potential to enhance the proportion of green space in cities and urban areas. Without exception, this technology can be applied to the roofs of all types of structures.
- Green roofs have several advantages, including architectural and urban benefits. Green roofs provide thermal comfort and reduce temperatures inside buildings in the summer, as well as perform better in the winter to heat the place than ordinary roofs. It improves the building's visual value while also providing psychological comfort to its occupants.
- Green roofs lower the temperature differential between the city center and the countryside (reducing the heat island effect), as well as provide areas for recreation and comfort for the public in residential areas, reducing the distance people must travel to visit public parks.
- The large-scale green roof is used in buildings with structural characteristics that make it impossible to handle additional heavy loads since this roof has low loads and is limited in its use because it can only be used in old local residential, governmental, and commercial buildings.
- Because of its high saturated weight, dense green roofs are used in buildings that can withstand high loads. It is also used by the general public because it can be installed in

local recreational and investment facilities, as well as government buildings, to serve as a resting area for personnel.

- The various forms and techniques for installing green roofs provide for a great degree of flexibility in implementing and constructing green roofs in any building and for any purpose, since they may be applied in local residential buildings, government and commercial buildings, and others. The kind and relevant technology are chosen for each building based on its structural tolerance. In current investment residential complexes, for example, the intense kind can be developed with full system technology to be used in the project.
- It is possible to grow any form of plant on the rooftops, but it is important to notice the types of local plants that are appropriate for the city's environment.

5.6 Conclusions

- The findings of the thermal measurements show that green roofs have the ability to reduce the temperature within buildings by reducing heat transmission through the roof. This is due to the green roof layer of plants, soil, and other materials acting as an insulator or, more accurately, as a cooling device installed on top of the roof. The energy savings and savings will be at a very high level, as the average temperature inside the building covered by the green roof was 4.34 degrees Celsius.
- Green roofs have the capacity to protect building roofs daily, monthly, and annual temperature swings inside and outside the building, which have a negative impact on the materials used in roof construction.
- We discovered in the analysis that The Towers Square building is entirely reliant on mechanical means (lighting ventilation) to offer thermal comfort inside the building, implying an increase in the consumption of electrical energy to give thermal comfort to users.

6. Recommendations

- There should be widespread interest in green roofing technology among urban designers, planners, and developers of basic city designs, at least in government and investment projects, with competent authorities monitoring the sustainability of green spaces and ground gardens and giving priority and increased attention to providing thermal comfort in the city's climate.
- To achieve the maximum thermal comfort, the work of green roofs should complement, rather than completely replace, the work of ground green spaces.
- Government agencies and local and central competent authorities must encourage projects that use new global technologies that focus on climatic, aesthetic, and other factors.
- The competent municipal and governmental authorities will devise an action plan that will provide aid, cash grants, and incentives to anyone who wants to implement this contemporary technology.
- Working to implement and apply green roof technology on government and local investment buildings to educate recipients about the importance of these technologies and the extent to which they can be utilized.
- Conducting courses and seminars that are adopted by the relevant authorities in collaboration with educational institutions to consolidate the concept of the green roof and introduce the different benefits offered by these technologies.
- The government should also address the issue of offering the materials used in the construction of green roofs (detailed layers) on the market at reasonable costs.
- collaborating with professional companies that provide facilities for green roof development and maintenance.
- Supporting practical research in this field on a moral and material level, as well as bringing the most recent means and requirements in the field of applying all that has economic returns that benefit the country, would make the country one of the developed countries in terms of using the best means to preserve the environment and provide the best energy consumption.

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