The Analysis of the Role of Green Walls in Reduction of Heat Islands in Tehran

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Abstract

With the development of urbanization and population growth in the use of land for construction of residential and industrial areas and other infrastructure and turning to remove more vegetation,construction materials and non-systematic misuse of cities,urban areas have forced some changes that pollution and poor air quality,dehydration,high temperatures are some of its results.The temperature difference between the central and dense big cities and its suburbs is named Urban Heat (Thermal) Islands that enter the city to a self-destructive cycle.In this way the hot and polluted air increase the city temperature in the central and dense big city,due to closure of wind passing ways and absorption heat by the most of materials in city surfaces and decreasing humidity,so we use more utilities and electricity for temporary relief.However,the generated heat return to the cycle by the facilities,causing to be warmer and upper city temperature and enhance heat islands.This has devastating and fatal effects on human health.It causing many diseases and encounter with loss of water resourses,drought and more polluted air.Then must find ways to reduce this phenomenon at the same time,such as:Planting trees(especially the shady type of them),vegetation(with increasing humidity and cooling environment),the use of reflective surfaces(rooftops and sidewalks,walls of buildings that organize most of city areas)which includes cool paving such as light-colored materials and create shadows on the floor, also porous and pervious paving,ligh-colored roofs,green roofs,use of green walls in the building,reduce facility outcome heat by using natural ventilation,reducing the height of buildings for local winds passage.In this research,one of the strategies have been fully reviewed namely the green walls and its role in reducing urban heat islands.And present the best model by examining a few built examples in Tehran.Correlation Research methodology is descriptive-analytic.Some results of this research are as follows:Green wall on the facade of the building acts as insulation and prevents thermal fluctuations by creating an air layer.Some of the radiated rays is reflected by the leaves of plants and the others are absorbed by plant and it cause surface evaporation and moisturing to the environment.By using of green wall in canyon(due to high altitude of buildings or topography)can prevent of absorption and storage of too much sun radiation energy during the day and also of anthropogenic heat.

Keywords: : Green Wall, Green Façade ,Living Wall , Urban Heat Island , Tehran

1. Introduction

According to MEA studies in 2005, health of the ground has been reduced and during the past of our decades has fallen about 60% that is causing a lot of problems .One of the most important of them is the reduction and disintegration of natural landscapes by the impact of human activities in the natural environments(Attmann, 2010).In other words, more horizontal spaces in the city have been used by ever increasing density of cities, development of human societies,lifestyle changes and settlement of people and increasing numbers of vehicles that lead to decreasing and lacking green spaces so that they eliminate from the city to obviate of need to residential space,office and etc. what will bethe result of this elimination? increasing UHI ,air and sound pollution, ruin the ecosystems and food sources therefore not meeting human needs and reduction of quality of life and wellbeing.

Furthermore in 2006,for the first time in human history, the proportion of urban population became equal to the rural population that has been occurred by ever increasing of urban population. Cities have more people than rural areas now that it has had a lot of results. In recent decades,land use and its coverage has many differences in major cities than in suburbs. The structure of urban design increases the temperature of some parts of the city. All of the city areas doesn't have he same temperature and they have higher or lower temperature than their neighboring areas with a different type of structure and urban design. This temperature difference root in factors such as topography,construction,used materials and etc. These differences are caused that the average of temperature degree in cities be a few higher than its suburbs. Parts of the cities that temperature difference occurs is called Urban Heat (Thermal)Islands which due to be anthropogenic can controlled and reduced intensity of that by using of strategies (Mazloomi ,2011).

Urban heat island was introduced for London at the first time in1878 by Howard Locke, then in the second half of the 19 century for Paris by Renault Emilyan and thereafter it was diagnosed in town and cities around the world (Gartland,2008:16). Manley propounded the so-called heat island in 1958. Later in 1967,Oak achieved equation to estimate the maximum temperature difference between urban and rural areas by calculating the heat island for eleven European cities. Many of heat islands researches in

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Tehran are identified where they are and some general solutions have also provided with analysis of daily and nightly temperatures and thermal images of the city. Such its effects and outcomes description that was published by the US Environmental Protection Agency(EPA) in 2009 or could mention to the quality of UHI calculation by James Wet that related to the Western Ontario University. In some research in 2012,Sasanpour and others examined the relation between user and increasing tempera'/ture and as a result increasing the heat islands in Tehran and also Shakiba and others determined Tehran heat islands. But in this research ,strategies of reducing urban heat islands is examined and role of one of these solutions that mean using of vertical vegetation cover is analyzed with a few constructed samples in Tehran to answer the research question.

2. The reasons of UHI importance and question of research

But why should be reduced and controlled UHI ? Creating urban heat islands has detrimental effects on life and health of human beings ,especially in the hot summer season. So it must be used more energy for cooling equipments in these areas and the heat from these devices enter into the open air that will be increase the areas heat temperature Heat islands cause air pollution and greenhouse emissions increasing that lead to the proliferation of disease and human casualties. Also it caused to come down the quality of drinking water that is the critical issue.

Due to harms of heat islands for human, the need to reduce the temperature difference is felt more than ever so that reduction of urban heat island has become one of the main objectives of designers and architects.

The question of this research is about one of the strategies of reduction of UHI that mean using of green walls in Tehran as a big,dense and polluted city .

- What is the best system of structure, construction ,and durability for Tehran and how does it reduce the urban Heat islands?

3. Purpose of the study

The purpose of this study is presentation some solutions to reduce urban heat islands and careful examination one of them(green walls) until at the end of the study will achieve the best type of green wall in terms of structures, construction site and the relationship between the choosing the type of system and plan demand.

4. Research method

To achieve results in this research, descriptive-analytical method of research is utilized by using of documentary study ,credible sources including articles,books, necessary photo collection for the introduction and better understanding of the research topic and field study of constructed examples in Tehran by authors. So that first of this research,mean urban heat islands are results of library data gathering but in the introduction part of green walls in addition to that is used of field study. But the part of case studies includes discussions and results ,results of field study and examination of constructed green walls (in 3 type of the buildings: office building ,public spaces and highway walls in Tehran) for analyze them with regards to constructed green walls by green space organization of Tehran municipality (headquarter of vertical green space development which is located in Goftegoo park and trial and error of selected systems.

In this research the heat islands, causes and factors of formation and their losses are described ,then strategies for controlling and reducing of this phenomenon and one of them that is the role of green walls in this reduction are examined.

5. Theory

5.1 Urban Heat Islands (UHIs)

Urban heat islands are the most common urban phenomenon in which some urban areas,especially city centers are a few degrees warmer than the surrounding area(Shakiba & Others, 2009 :2).Satellite investigation shows that all the major cities on the earth is involved in with such a problem because of the removal vegetation and plants replacing them with materials,especially dark materials of construction. During the summer season, along with the process of absorbing ultraviolet and infrared emission, In each region, roofs, buildings, street and dark spaces absorb heat and then send it to the air. Due to the fact that ceiling are almost dark in Tehran,and these are about half of Tehran's areas that absorbs heat from the sun and keep it by themselves .This phenomenon increases the temperature of the residential areas from 2-15 c and it called Heat Islands Phenomenon. The heat not only increases energy consumption for cooling buildings but also cause pollution in the atmosphere and on the surface of the land. Since human is changing the natural characteristics of the cities in the process of the urbanization and its expansion,directly and indirectly affects on the thermal energy that enters the urban boundary layer. Their ultimate impact on the local or small scale climate ,medium scale and even large scale is impressive and clear. In rural areas,solar energy evaporate water of plants and soil. Latent heat of evaporation causes change mode of water from liquid to vapor which remain constant temperature of these areas and prevent from increasing of that. But in cities with less density of soil and plants the large amount of incoming solar energy bring about directly the heat of the streets and buildings. During the night the stored heat in streets and buildings are sent into the air slowly and slow the process of decreasing temperature. This effect causes to warm the metropolitan area. Taller buildings store more heat and slow the process of air cooling. Vehicles, factories and air conditions create more heat and exacerbate heat island effect (Behtash & others,2013). Plant deficiency usually causes other problems such as increasing of various pollutants level in urban air especially the wide range of

human activities (industrial production,agriculture,land use change,etc)that increase concentration of thermogenic contaminator gases(carbon dioxide, methane,etc.)that acts like a blanket and hold the heat that normally going out of the atmosphere near the earth's surfaces. This process is called the greenhouse effect(Ghiabaklou ,2011)(one of the related concepts with the air pollution is urban heat islands)that water and rainfall loss,increasing of noise pollution and mental health problems and etc. are result of that. Urban heat island represents enclosed isotherm lines of an area of a surface that is interference by human more than the others. The highest temperature is in the center of town that is full of buildings and lowest is around the city countyside. Urban heat islands usually occur in the shadow layer that is close to the ground. Heat extended vertically to form a dome heat near the earth(voogt,2007) . Urban heat islands are more severe in summer when the sky is clear and the wind is not blowing. The opposite occur when heavy cloud cover block sola radiation and reduce daily heat of town (Akbari & others ,2008:2)

5.1.1 Types of urban heat islands

-The atmospheric urban heat islands which include tow sub-categories:
- Boundary layer urban heat islands : In the areas of roof tops and trees upward.
- Canopy layer urban heat islands : Where we live from the ground to the top of the trees.
- Surface urban heat islands

-Surface urban heat islands (SUHI,USL): On a warm and sunny summer day, the sun can heat the surfaces temperature between 25-50 c warmer than the air temperature unless wet or shaded surfaces exist to stay close to the air temperature. The surface urban heat islands exist at night and in the day but its intensity in the day is more than night because of sunlight. The average of daily temperature difference of city and countryside levels is about 10-15 c and its nightly about 5-10 c . The largeness of urban heat islands change with season due to changes of sun intensity furthermore land cover and air. As a result the surface urban heat islands typically are larger in summer and related to the used materials in the town and have different capabilities of reflection coefficient , the coefficient of thermal emission or heat emission and heat capacity that mean the heat can be stored (Akbari & others ,2008:2) .

-The atmospheric urban heat islands : Warmer air is compared with cooler air near the countryside that define the Atmospheric urban heat islands.

- Boundary layer urban heat islands : BLUHI/UBL
From the rooftop and treetops begin until about the point where urban landscape can notaffect the atmosphere which mean not more than 1/5 km from the surface.

- Canopy layer urban heat islands : CLUHI/UCL

These are in the layer of air where people live, from the ground to the top of the trees and the roofs and the highest and the most common of the two types.

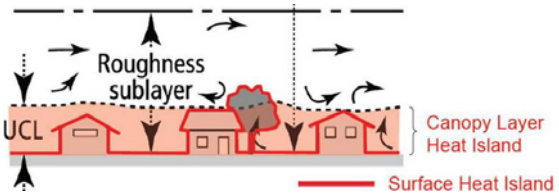


Fig.1.Location of canopy layer (Source: Voogt,2007 :5)

5.1.2 Air and surface temperature dependency

The temperature of the surface have an indirect but undeniable impact on air temperature , specially in canopy layer that is closer to the surfaces. For example , parks and green areas which have normally cooler surface temperatures will help to cooling air. On the other hand,
Large made areas usually heat airs because the air is combined with atmosphere . Then relation between surface temperatures and air is not stable and usually air temperatures have lower difference to surface temperature in a region(EPA,2009:4) .

5.1.3 Factors affecting the urban heat islands

-Geographical location include weather, topography and rural environments.
-Dimensions of the city that is related to the form and function :
The shape of the city (urban surfaces) contains materials : thermal characteristic and land cover (sidewalks, roads, etc.) and type of them in terms of surface roughness (leading to increased reflection of solar radiation and prevent air from flowing freely),
Geometry : the size and shape of buildings , wind flow passing through them, solar radiation is reflected back into space and green space and urban performance contain of use of energy , water and produced pollution.
- Synoptic weather: Wind and Cloud
The time : day and season (Voogt,2007:8).
-City population: The population density per unit of area of the city and the intensification of the heat island effect and whatever there are more population density the temperature is higher .

5.1.4 The effect of the surface on the heat and flow of surface water and urban heat islands

Highly developed urban areas on the left are made of 75% of impervious surfaces which had lower levels for perspiration and evaporation (approximately 30%) that its result is reduce ground water levels but on the right that have less than 10% impervious cover , measure of the evapotranspiration and ground water levels have gone up , which will cause less heat islands.

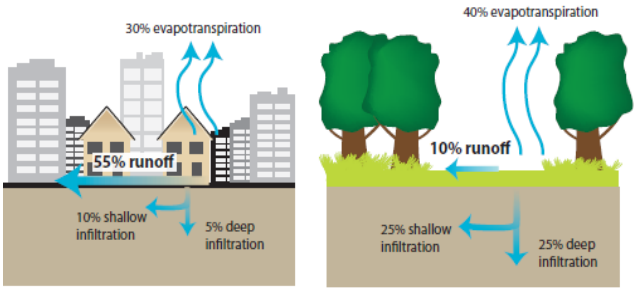


Fig.2.Effectofsurfaces onthe heat islands(Source: EPA,2009:8)

5.1.5 The development of urban heat islands

This process is fully illustrated in the following figure. Artificial heat ,narrow streets, levels of insulation,dark pavement,etc that all cause urban heat island.

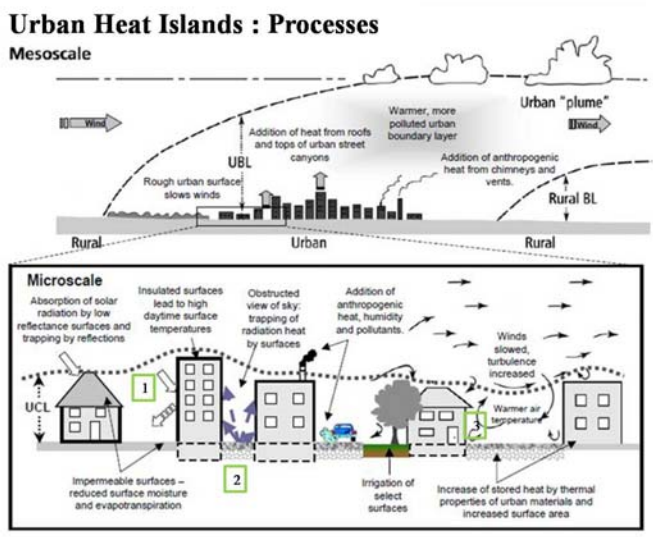
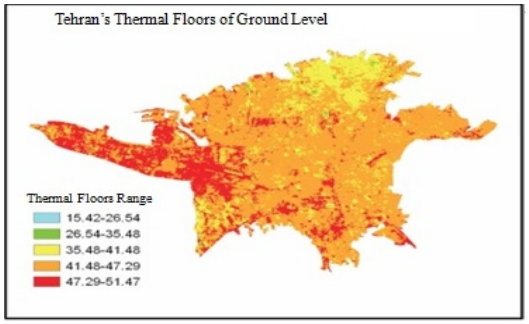


Fig.3.Heat island development stages(Source: Voogt,2007:6)

In term of time, cities are warmer than surrounding areas from noon on and nights that this increasing of heat has a direct relation with the size of the cities and their latitude. The differences between inside air of city and around of that are more intense whatever the city is larger and in higher altitude(Ghorbi,2013).The most important causes of the increase trend of Tehran's temperature are heat release of antropogenic heat from heating of homes, cars, factories,and also absorption of reflection of ground long wave radiation by the large quantities of atmosphere pollutants in Tehran(Sa'adat abadi & others,2005). In this case even can be considered every person of the city as a source of heat producing. Tehran has been located geographically at 51:17"-51:33" in east and 35:36"-35:44" in north latitude.Tehran and the wall of high mountains in the north and north east,it has created problems in terms of natural ventilation(Sasanpour & others,2012:5).Affecting factor on spatial intensity and pattern of heat island is wind and direction not air pressure.The proof of that is the intensity reduction of heat island when wind has the highest speed so that the minimum intensity of heat island has occurred the hours of 12:30" to 18:30" .The maximum intensity of heat island coincides with hours's minimum speed of wind and maximum intensity of heat island has occurred between the hours of 00:30" to 09:30".Tehran has high population density and vast expanses in comparison with other cities with dating back decades urbanization and the workshops and factories focus in the city limits has prepared conditions for creation of anthropogenic heating (Shakiba & others,2009). In the most of times,wind speed is so lower than 9 meter per second(the speed necessary to prevent the formation of heat islands)and most of the metropolis of Tehran due to its geographical position in influenced by local winds. Local winds could play a significant role in adjustment and change of heat island in Tehran. These winds depend on time of day and change in different seasons and months(Sa'adat abadi & others,2005:6). In figure, map of thermal classification and Tehran's heat islands represents the following instances .This schedule shows Tehran thermal classes based on their thermal limits.



Temperature(c)	Thermal Ranges
15/42-26/54	So cool
26/54-35/48	Cool
35/48-41/48	Normal
41/48-47/29	Hot
47/29-51/47	So hot

Fig.4.Tehran heat islands(Source:Shakiba& others, 2009:8)

In this division on heat maps, heat islands are include very hot temperatures limits. Heat islands of Tehran coincide on commercial centers,airports,transportation hubs,dusty areas and pristine .

Impermeable surfaces and soils have heating effect because of absorption and storage of solar energy thereupon temperature increases with growth of impermeable surfaces and soils and decreases with growth of vegetation because of evapotranspiration that has cooling effect(Shakiba& others, 2009:12).

Commercial and high-density residential areas such as Imam Khomeini Square, marketplace that is the most important market areas of Tehran where have large population and a high volume of traffic , also their

construction materials have a high thermal capacity and lower reflections. On streets and highways with high traffic, such Khavaran and Damavand highway ,the scope of the railway square and the railway station ,South and West Terminal (in addition to the lack of vegetation , high density of population and vehicular traffic), in areas with high population in south of Tehran , such as Hejrat and Dolatabad town , there are industrial workshops in addition to residential areas and anthropogenic heat generation. In airports of the city such as Air Force, Ghal'e Morghi and Mehr'abad low vegetation ,asphalt surfaces that has less reflection levels and high thermal capacity and marginal barren areas of Airport ,arid and semi-arid areas in the southern and northern Tehran suburb of dry soil due to high thermal capacity and lack of evapotranspiration ,in industrial areas of west and east of Tehran due to impermeable surfaces creation ,low vegetation ,heat from fuel and pollution ,all of these have been creating urban heat islands in Tehran(Shakiba& others, 2009:12).

With regards to the extent of heat islands in Tehran , creation of unfavorable environment and decrease quality of the human living environment should be applied practical maneuvers to reduce this phenomenon and subsequent losses.

5.1.6 Urban heat island reduction strategies

Urban heat islands are creating because of the kind of urban planning that we've applied and of course weather conditions of areas. The following strategies should be used to reduce it because the temperature has the positive relation with impermeable surfaces and inversely relation with vegetations:Increasing humidity and cooling environment , using of natural ventilation to reduce heat from the facility, and green roofs for mitigating and treating pollutants, and cool floor like materials that does'nt have dark color, reduce the height of buildings for the better passage of local winds, and creation shadows on the floor, etc.

-Trees planting(especially the canopy type)and vegetation ,maintenance and protection of existing urban trees, to reduce heat islands is essential.

-They have cooling effect because of the shadow and moisture that is released from the leaf surfaces. Trees are planted in the right places for shading to reduce costs of energy consumption and increase property values. Trees of streets and parking will help to reducing temperature (EPA,2009:18). Shaded surfaces are cooler than the other materials at the peak of heat about 11-25 degree and evaporative cooling of plant can reduce the air temperature 1-5 degrees at the peak of summer lonely or with shading(Mazloomi ,2011:8).Vegetations are effective and also green roofs and walls have a significant influence in reduction of this issue so that through a few strategies fight with it .

- Reflective surfaces mean roofs , pavements and walls of buildings that make up much of the city .

*Roofs include about 20 to 25 percent of developed urban areas. On a hot sunny day of summer, a black roof reflects the sun's energy 5 percent and absorb more than 90 percent of that and can raise up to 80 ° C roof temperature. But a cool roof reflect most of the solar energy and the roof temperature is going to about 50 degree. Also using of a green roof insulate the roof with putting a vegetation on that and cause reduction of its temperature through evaporation and shading (EPA,2009:20).

* Pavements include around 30-45 percent of developed urban areas and absorb heat during the day and release it at night but its temperature will not rise like roofs. The use of porous and permeable pavements will result the air flow transfer and reduction of thermal storage addition to collecting water from the surface of the sidewalks and evaporating them (EPA, 2009: 21).

* Walls of buildings can be more effective because of their greater extent than roofs. The wind flow has been stopped because of high altitude of some buildings thereupon hot weather remains between buildings for a few days in the summer but with using green wall can be helped by its evaporation influence to cooling the air and taking aerosols to purify it by leaves .

This is the solution that will be described completely in the following namely green walls.

5.2 Green walls

As previously mentioned, accomplished studies of green walls has been mainly to determine the optimal details, reducing energy consumption and etc. In one study, reducing the amount of greenhouse gases were analyzed by using of green walls (Perini, 2012) and that is described construction methods of green walls and vertical garden, benefits and types generally or another study is examined reduction of noise pollution , improve the urban environment and etc(Loh,2008). Behtash and others in the study entitled " Evaluation of effective dimensions of urban form on air quality " have examined the green walls (Behtash & others,2013).

The greening of building envelope is a new field that has expanded in the ecology, cultural and built environment quickly. This is an opportunity to combine nature and buildings(integrating various functions (Perini,2012:1) The closest form of vertical gardens is dated from 2000 years ago in the Mediterranean region. The first decorative roof garden was built primarily by Mesopotamian civilization(the hanging gardens of Babylon)(Perini, 2012: 1). and then expanded in the Viking period (.Bjerre, 2011: 9). Modern green roofs and facades returned to 18-19 AD which is found in northern europe areas such as self-growing climbing plants that have been used for shading on vertical surfaces of Mediterranean**.**But today,this type of building envelop combine modern materials with advanced technology to achieve the stable operations of the

building. The first research on this type of envelope started at 80s (Perini, 2012: 2).

Green walls are modern technology that slowly find themselves in metropolises in the world. In other words, the green wall is said to to wall that be independent structure or part of a building is covered with vegetation (AIA, 2008). A living green wall is vertical combination of herbs and other natural ingredients that are unsanitary and eliminating the harmful toxins and pollutants from the air we breathe . Today green walls are designed with retaining structures for specialized . This technology has a wide range of applications and significant benefits in terms of environment , energy saving , economy , social issues, psychology , recreational opportunities , prevent greenhouse gas emissions and create heat islands , improve air and water quality , provide habitat for some creatures , food production , job creation , aesthetic and artistic aspects . Therefore, we can say that these systems have been defined in line with the fundamental objectives of sustainable development , while the roots are the components also practice it. Used technology and materials in it depend on local weather and wind (Perini, 2012: 81) that in the following investigate the types,advantages and disadvantages of each one and materials **.**

5.2.1 The green walls types

-Green Façade - Living Wall

- Green Façade

Green façade is a kind of green walls in which a simple structure (such as metal frames,square panels and cable systems for retaining structure)for scaffolding attached to the wall of building ,and acts such as anchor for creeping and climbing plants:Vine, ivy and etc.Green facades can rely on fences and columns or be built as an independent structure. Green facade scaffolding structure can be different materials such as wood, steel (galvanized, stainless, coated), plastic or aluminum, etc., each of this materials will follow the usage , aesthetic aspects and different functions(Perini, 2012: 81).In this type of green wall, types of climbing plants at the bottom of the wall and on the ground and in the absence of possibility planted in pots and lead to upward by scaffolding that is installed on the wall .In its more complex form, the plants can be spaced flower boxes on balconies, roofs and facades also be repeated on them. In this system plant turns and goes up from the building while it has root in a soiled bed . Recently for green façade is considered support structure (Rahimi,2011:4)

The table No-1 examines the types of green facades on the type of structure, advantages and disadvantages of each and every type and image is also displayed

Table .1
Types of green walls according to the structure

Types of Green Facade	**Characteristics**	**Benefits**	**Disadvantage**	**Figures**
Modular Trellis Panels	-light / Galvanized steel grid - Located modular lattice panels together -Connected to the wall/ Distance from the main wall:3cm - Planting plants in the ground and plants grow indoor the panels	-Covering large surfaces - Forming panels to create curved shapes - The possibility of creating a bridge by green walls and independent green wall because of curvature and strength of panels with necessary measures - Entering less stress to the plant -Normal irrigation	- Best mood of construction on concrete wall because of the short distance with the wall , plants growing and filling contour - Final growth : Fast or slow depending on the size of the constructed green wall - Wall beginning from the ground	5. 
Modular Panels	- Connection of light steel structure to façade wall with distance to prevent the destruction of façade / Scaffolding connection location depends on the type of building structure / Essential mobile connectivity for overhauling the structure without damage to the irrigation system -Metal holder boxes of plants or polypropylene plastic or industrial textile (geotextile = lightest) -Depth of panel between 6-25 cm based on plants / dimensions depending on the design panel -Planting herbs in panels	-Planting in bags made of plant fibers in each box in order to prevent loss of plant, prolonging the irrigation interval -Ease of moving boxes if needed, such as destroying of a plant or change in the appearance of the green wall -Achieving the final result in less time -Auto-drip irrigation by passing tubes from each row box -Green wall beginning From anywhere in façade not of the ground	-Less Possibility of Plasticity - Entering stress to the plant because of height - Planting and limit the choice of species herbs for planting	6. 

Cable system	-Cable grid with high elasticity + clamps + Supplements Equipment -For plants with rapid growth, scrollable, full foliage -Determine the distance between the hubs in terms of planting herbs(max50cm) -Planting herbs in the ground/herbs growth on the cables	- Ability to integrate with wire net system - Supports the plants on the wall, allowing different size and type of traction & Contraction of cables by hubs - Entering less stress to the plant -Normal irrigation -Creating of air corridor on the wall	-The low distance between the hub (supports) -Need to time for final growth -Green wall beginning of the ground	7.  
Cable-Tensile system	-Another type of cable system for use in green facades with large volume and vast surface -Planting herbs in the ground or between floors or roof	- Ideal for public spaces: walls of office buildings / public spaces / large residential spaces -Entering stress to the plant according to the planting situation: low to high -Normal irrigation -Creating of air corridor on the wall -Beginning of construction of green wall from several directions	-The low distance between the hub (supports) -Need to time for final growth	8. 

Wire net system	-Cable grid with high elasticity + clamps + Supplements Equipment -For slow-growing plants and need more support - The distance between the hub : 15-30 cm	- Ability to integrate with cable systems -Easy installation -Ability to create different sizes and patterns - More flexible than cable systems -Capability of various design - Entering less stress to plant -Normal irrigation	-Less distance between grids -Need to time for final growth	9. 
Stainless steel frame	-Used in non-load-bearing wall façades -Independent structures with steel frames and cables to keep the plant -The distance between façade & frame -2days for installation	- Firmly on the ground and not on building -Airflow on the surface of the wall -Normal irrigation	- Final growth's time consuming due to the creation of high altitude frame	10. 
Combined techniques	- Plant herbs in elsewhere and transfer insulated and isolated containers on the wall -Heating cables passing through them	-Very fast final growth of plants -Green wall beginning From anywhere in façade not of the ground - Prevent frostbite roots -The use of 4-month up herbs		11. 

(Source : Authors, according to the analysis & comparison of this research's references)

Figs Source :
No.5. AIA , 2008,6
No.6.www.elmich.com
No.7. Carl Stahl DecorCable Innovations
No.8. www.greenlinkintl.com:IFMA,2013,49
No.9. Carl Stahl Décor Cable Innovations
No.10. Bjerre , 2011:18
No .11. Bjerre, 2011:19

* Used systems in the green facade can also be divided in two groups structurally : the 2-dimensional and 3-dimensional 2D.
System includes rigid and flexible 2D system that the rigid type is bigger than the flexible type. Overall flexible 2D system will want easier maps and more traditional equipment. 3D systems also include 3D system of panels, which are made from thin gauge steel wire and Or the other one that uses structural panels with an integral truss without the need to a surrounding frame for strength or installation.



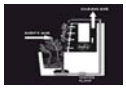
Fig.12. Fig.13. Fig.14.
Fig .12-14: Installed 3D green façade

Fig .15: 2D green façade with steel cable
(Source: greenscreen.com)

Table . 2
Types of living walls according to the structure

Living walls

Living walls composed of pre-planted panels that are installed on the facade of the building vertically and by the lightness structure ,or they are independent self-supporting . Living walls are composed of square and rectangular panels or vertical modules that are solid to the wall or structure frame and with the possession of the plants will keep of them . Modules panel include polypropylene , plastic materials , geo-Tex tile, irrigation system and plant growth environment . In this system, different types of plants can grow up which includes a mix of overlying soil, ferns, small shrubs, permanent flowers and eatable plants . Living walls work well in full sun, shade and internal applications and can be used both tropical and temperate climates. Due to the variety and plant density,living walls need for more care and maintenance (irrigation , nutrients and fertilizing) than green views. Modular living walls system have been taken from modular green roof system that includes square and rectangular panels. Nutrients also spill into this reservoirs and irrigation system from the reservoirs at different heights achieve by gravity . They can also be used in interior spaces. The following table(No2) examines the types of living walls by type of structure , advantages and disadvantages of each one and its image is also displayed.

Types	Characteristics	Benefits	Disadvantage	Figures
Active System	- With a biological filter -Integrate in ventilation system and natural acting natural cover as cleaner and adjust heat engines - Pull fresh air through a vent into the system and play it indoors - Placed plant root between two layers of industrial textile and feed them through the enriched water with nutrients	-Similar Modular Green Roof System -Increasing of air purification capacity -Using of hydroponicsystem for reduction of weight	- Putting a ventilation system and the engine behind the green wall - Maintenance of green wall usually behind glass wall in order to better control of the air	16. 
Passive System (modular living wall)	- Connection of light system with distance to the building façade or its structure - Square or rectangular modular panels - The implementation details of panels are different depending on the manufacturer, different genus: plastics, polystyrene, polypropylene, ceramics, metals (steel, aluminum) textiles industry (a felt) or light concrete - Usually drip irrigation system - No mechanism for air circulation and keep them open for a relative improvement in air circulation	-Using of hydroponic system for reduction of weight	-Reduction of Air purification capacity	17. 
Living Felt Wall	-Very simple mounted system on metallic frame +a mounted and fixed PVC plate on a metal frame + fixing felt screen vertically on the plate -Felt made of non-decay materials with high capillary power -Placing plants in felt - Irrigation system of water: pumps and picker systems with feed materials - Planting plants in the ground, then transfer to bags or planting inside the bag	- Weight-bearing of living wall. -Allowing airflow between the main wall and living wall ,resulting in cooling the main wall - Achieve results more quickly	-Need to pomp for irrigation of plants	18. 

(Source: Authors,according to the analysis & comparision of this research's references)

Figs Source:
No.16&18 .www.greenscreen.com
No.17. Green Living Technologies.com

In the choice of type and appropriate system of green wall, according to the overall design green wall on the facade, position of building façade and funds intended , the green wall (living wall,green façade)or a combination of both types are selected for the project .

Each election systems of green wall have their advantages and limitations and due to the special circumstances and needs of the project one or combination of them can be implemented.

In some buildings, vertical green space can be combined with the construction by using of the traditional system of flower boxes on the balconies and under the windows if the construction of none of green wall variety is not possible in concept of its new technology for any reason .As well as in the overall design of green wall on the building façade , combining green wall with facade of the building should be designed according to the style and architecture of the existing building which the main elements of the building is preserved. Also in the overall design of green wall, harmony and balance with building façade is established in such way that green wall as a part of the building design is combined with the existing façade in principled and the proper shape .

6. Case study in Tehran ,Iran

The implemented green walls (green façades) in Tehran are in 3 type of office buildings , public spaces and highway walls that in this section will be discussed these that's mean constructed green wall in Nature Bridge (public space) , two constructed green walls in the municipality façade of region 1 and 3 (office space)and constructed green walls on both sides of Hemmat highway from Shariati Ave.

6.1 Nature bridge

Green wall is constructed at the end of restaurant segment that is located on the underside of the bridge(on Modarres highway) . System of this green wall is modular panels so that the metal structure is installed at a distance of about 3-2 cm from the wall and its height is about 6 m that is mean from 10cm from ground level up to about 20 cm below the ceiling . It is possible to the wall mount and dismount there without structural damage because of choosing this system . In this case was used from boxes of stretched polypropylene plastic (light) close to 15 cm deep, because the type of plant chosen for the wall. Irrigation system is all-round pipes (location shown in the photo) that placed along the wall between the rows of boxes and these are doing auto-drip irrigation. From advantages of this system can be mentioned to the planting herbs in panels and the ease of moving boxes if need like deterioration of a plant or change in the appearance of green wall , achieving the end result in less time and their disadvantages are the stress that enter to the plant due to the altitude. This wall along with furniture and a roof over them is created pleasant and relaxing atmosphere .

Fig.19.

Fig.20.

Fig.21.

6.2 Region 1 and 3 of Municipality

The green wall in the main façade (side entrance stairs) of Tehran municipality of region 3 which is located in Shariati Street is constructed . The system of this green wall is modular panels type but its metallic is installed without distance with the main wall. Height of that is about 1 meter in the center and about 1.5 meters in sides that is mean it is starting from height of 1.5 meters from ground level and goes up. That's why the 4 metallic stands are used to transfer the weight to the ground. In this model, the square boxes of polypropylene plastic (30 * 30) and the layer of industrial fabric (or geotextiles fabric) for soil moisture retention and most importantly, it is used to prevent soil loss . Because of the depth of selected plants (ivy screw) is about 15-10 cm .The irrigation system is drip automatic using pipes in each row that at certain intervals times will be reviewed and modified by co-executor. From advantages of this system can be mentioned to the planting herbs in panels and the ease of moving boxes if need , achieving the end result in less time and their disadvantages are the stress that enter to the plant due to the altitude .

Fig.22.

Fig.23.

Fig.24.


Fig.25. Fig.26.

The constructed green wall on the municipality lateral façade of region 1 that is located in Qods square and beginning of Niyavaran st. has a design of the flag of Iran with flowers and ornament plants and dimension about 1.5 * 3 meters ,has been located at a height of approximately 2 meters from the ground . But due to defects of irrigation system and lack of proper insulation, water entered into the first floor space and there was no choice but to dismantle it because of not to be responsive executor of plan.

6.3 Wall of Hemmat Highway

The Hemmat highway wall on Shariati Street intersection has two different types of green wall. On the right, a system like tensile cables is constructed in this way the progressive and full foliage plants have planted and grown on top of the concrete wall of built-in space and were just hanging on the wall . In this case, less stress enters to the plant,and its watering is very simple and easy to fertilizer or replacing soil . It doesn't enter weight and load into the highway wall that is prefabricated due to not using of the metallic frame and soil in wall . But it needs time to ultimate grow.



Fig. 27. Fig .28. Fig.29.

But in front of this green wall, on the left side of the highway near the underpass, green wall has been constructed of modular panels. In the first of 4 image, how to connect to the walls of highway structures and the next pictures are shown how irrigation. The structure is made of bars network which is kept boxes and its weight gives to the box section profile that can be placed vertically and these profiles have been transferred the load into the plate which are bolts to the wall . and the entire structure place at a distance of about 2 cm from the wall.


Fig.30. Fig.31.


Fig.32 . Fig.33.

This structure have been constructed regardless tolerance scale of the highway wall against additional loads . It is due to wrap up sooner and grow more plants in this model . The irrigation system is drop irrigation using pipes in each row and also there are sprinklers at regular intervals . Boxes are square polypropylene plastic (30 x 30) and have a layer of industrial textiles to maintain soil moisture and more importantly, it is used to prevent soil loss. The depth of that is about 15 to 10 cm because of the kinf of selected plants (ivy screw) . From the disadvantages can be noted to its junction into the pre-built highway wall and also entered stress to the plants . But the benefits can be modular and plants boxes which are easily replaced in necessary situation or moving plants.


Fig.34. Fig.35.

In the studied samples addressing the issue of structure and implementation type in according to the definitions of green wall systems, the best applicable option for Tehran is introduced .

Now effectiveness of implemented models to reduce heat island have are examined. It seems that constructed green wall on the Nature bridge has more decorative until functional aspect because the bridge has been constructed between two parks And although it is located at the top of a highway with high noise and air pollution but the effectiveness of their parks and vegetation on this issue is more than a green wall with limited size. In any case this green wall with shading prevent absorption of solar light ,and by its evapotranspiration causes cooling the surrounding air . The green wall on the municipality building façade of

region 1 was in the right place because locating in the tumultuous square and field of pollution created by crossing cars and locating in the western front of building which absorb western annoying light of summer and late in the day returns to space. As a result from two aspects reduced heat island that is mean in addition to reducing the absorbers levels , with shading on the part of the western front and evapotranspiration has also been caused cooling air ,and also had helped to clean air by attracting dust and air emissions. In terms of dimensions are such that not to prevent the view out of the window (from inside to outside) and would not distort the identity of building. But with all the mentioned advantages, choosing the wrong irrigation system and no handling ,is lead to dismantling that.
The green wall of municipality building façade of region3 has been constructed in the eastern and entrance façade which is very high traffic and full of polluting gases that is prevented absorption of solar energy by shading on the eastern front in the summer and like the previous sample with evapotranspiration has also been caused cooling air ,and also had helped to clean air by attracting dust and air emissions. In terms of size it is the same way too that has not prevented to see out of the window and damaged the building's identity. But it could be created on a larger scale or in several parts of the facade to have better and greater efficiency.

In both cases of highway wall,using of green wall causes reduction of heat absorption and returning it to the environment late in the day , reduce air pollution due to absorption pollutant gases by leaves , raising the humidity in the air and cooling that. But in terms of structure and safety in the crowded space should be used of green wall for pendant and similar cable system until built extra load doesn't transfer be or is considered in the design at the beginning.

7. Analysis

-In Tehran sometimes wind disrupted and can not remove the heat and air pollution from the city and heat and pollution remained a few days in between the buildings and creates unfavorable conditions.

- The high temperature in the city and in the summer, means more energy consumption for cooling equipment in other words, for each temperature should be consumed about 2 - 1.5 percent more electricity which of course in big and dense cities the rate sometimes reaches 5 to 10 percent to reduce part of the harmful effects of heat islands, causing pressure to electricitical generation systems and Installation , have led to increased production of carbon dioxide and this cycle continues until affect the human health in the form of public discomfort, difficulty breathing, muscle cramps, heat exhaustion and heat-related deaths, especially in children and the elderly.

- Green walls with water recirculation system used to reduce heavy water pollution. It does this work with non-water-soluble nutrient absorption . This nutrients are the mineral bacteria that microscopic organic components prepare them for plants . Unfortunately, in the examples of the numerous reviews in Tehran, , the used water by the occupants of the building(waste) has not benefited in irrigation system of green walls which is also due to creation a special facility for separating the effluent from wastewater.

- They act as a producer of oxygen and raise air quality of its location with attracting dust and dirt by their leaves. - The most important function of green walls is creation an air layer on the surface , shading , Sun-ray absorption and evapotranspiration and entering the moisture into the air.

8. Conclusion

According to the provided description , temperature levels are reduced by the temperature reduction of the building walls which causes to reduce of surfaces heat islands and on the other hand the air temperature near these surfaces is also reduced with that thus itself causes reducing the urban heat island of canopy layer. Heat island of surface and canopy layer are more important because it raises the temperature in the boundary layer and lead to climate changes . So in order to solve or reduce it, we can start from living place and the nearest location by following a few tips to help reduce it.

***** The best type of green wall in highway walls is made of the hanging system of wild plants or tensile cable system . If the load of green wall is considered in the calculation before wall construction , the best type of system is modular panel .

*****The best kind of green wall systems for public buildings is the modular panel system, which it is easily dismantling in addition to creating an insulating layer of air on the surface, and also it earlier wrap up .

*****In public spaces, according to the extent and level of need, can be used of panel system and next to it by planting wild plants and hanging them at different levels is decreased of the plant stress to a better outcome.

1- with using of green wall in canyon that have been created due to high altitude of buildings or topography can prevent of absorption and store the sun radiation energy during the day and anthropogenic heat by using of cooling systems and vehicles.

2. In the system of green walls irrigation can be used of building wastewater that make high percentage of used water that is far better than using raw water .

3. The best way to secure implementation of green walls is mandatory construction from on behalf of the relevant organizations for new buildings by taking the extra load and details of its implementation in the design and initial calculations but if you are planning for a constructed building or wall should be considered building age and structure.

4. Green walls can be applied in glazed of buildings as façade and also itself standed on the sidelines of streets and places that can not provide the required space for planting trees . In this case they cause shading on the surfaces of streets and highways, absorbing aerosols, air purification, emissions and produce oxygen and moisture.

5.If in the industrial towns and production workshops are used of enough green spaces which can be a combination of horizontal green spaces and planting trees and vertical green spaces and green facades in building exterior and living walls indoors , they have enough vegetation cover in addition to load carrying vehicles and not blocking roads and do action of air purification, oxygen production, requirements evapotranspiration and shading done and reduced from cooling and heating load and ventilation of workshops and creates a relaxing atmosphere for the employees of all categories.

6. It's better that the required herbs plant in specific environments where crop plants after they reach the desired size of those used in the manufacture of green wall until the speed of operation goes up and in the event of plant failure quickly replaced it with a new plant.

7.According to what was said the amount of heat generated in cities is related to the facility of air conditioning and heating and cooling .By using of interior green walls (living walls) can be ventilated indoor air and prevented of a large part of the production of heat from the facility because in this system the air that circumstances and produced by plants and roots which move in the entire space with fan and filter .

8. Using of green wall in the building facade in a way that has optimum lighting conditions causing reflection a part of that and absorption of the rest that it causes to produce humidity from the plant and soil and growth of the plant .

9. Air layer that placed between plants and building shell acts like insulation and avoids temperature fluctuations .

10. Shadows of leaves on the wall prevent achieving sun rays to the wall and absorbing energy .

11. In the development stages of heat island figure , three area marked which by green walls construction in these areas can help reduce the heat island and cause to break down the dome curve of heat island over the city in this posture heat can be removed and prevent its accumulation.So that in stage 1 by absorbing the sun's rays and shading on façade prevent of reaching them to the building and pavement.

12. The cable – tensile facade can be used in the green façade with large volumes and extent such as office buildings walls, public spaces or large residential spaces, industrial spaces, streets walls , etc.

13. The using of modular trellis panels on old concrete buildings are fit because of lightness and not to bring in the pre-unaccounted additional load and also plants humidity doesn’t hurt shells in this kind of green walls.

14. For façades that is expected its wall to have no bearing capability can be used stainless steel frame type and all the pressure and the green façade load is taken by this fram .

15. As mentioned in Tehran workshops and factory focus in the city limits are provided the conditions of anthropogenic heating and pollution and heat islands in Tehran matches on the commercial centers, airports, transportation hubs and dusty areas and pristine. In commercial and high-density residential areas such as Imam Khomeini Square, the commercial center of Tehran that is the most important market area of Tehran must be used of green walls because building materials have a high thermal capacity and has less reflection.

16. In areas with a large population in southern of Tehran should still be used of green wall modular panels system for some parts of the facades of residential buildings, industrial buildings and walls such as Hejrat and Dolatabad town.

17. In airports of the city such as Air Force , Ghal’e Morghi and wastelands of airport margin , should use the green wall that does not pose a problem for flight safety.

18. To hide the mechanical or ugly parts of building ,walls of parking, highways, factories and industrial buildings, using of green wall is recommended according to the used surface.

19. In Figure 3, three locations marked with numbers that can be the site of the green wall and the points that are most effective in its own.

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