Journal of Renewable Energy and Smart Systems *Vol.1, No.1, 2024: 7-18*

Renewable Energy and Smart Systems

journal homepage: https://sanad.iau.ir/journal/res

Study the function of "cool roof covering" for schools in mostly hot or moderate climates

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Article info

Keywords:
educational building
cool roof
climate designing
sustainable schools

Article history:
Received: 8 Apr 2024
Accepted: 14 Jul 2024

Abstract

Educational buildings in Iran, normally have short walls with large scale space and roof. Large scale roof as an external exposure part to sunlight or regions climate, it can have a major role in receiving or wasting energy. Sunlight radiating on the roof is a key for absorbing heat in hot regions based on warmth intensity and time length lead to the warmer top floor and more expenses for cooling up the building. In this article, the "cool roof" as a solution for controlling the roof heat absorbing and school's roof refinements in hot regions also are included. This case study includes: representing the various cool roofs, its advantages and disadvantages in different regions and studying the of cool roof covering in schools all around the world. In addition, by evaluation the advantages and disadvantages of the cool roof covering in school buildings based on the construction condition, rebuilding condition and maintenance and relating expenses. The optimal and affordable cool roof suitable for Iran's schools are recommended.

1. Introduction

As the school's construction process in Iran is under the supervision and monitoring the schools renewing and developing and facilitating organization, and typically because of the same pattern that it's been using in different regions, the flaws are repeating in vast scales. The majority of schools in Iran is governmental،the problems due to energy consumption in school buildings have a lot of financial loss for the ministry of education and the budget that

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can be used on upgrading the educational system should be spend on cooling or heating systems. School buildings with low height and large space in different climates, the roof is one of the main factors in a building that covers a vast part, therefore; there is a major effect on building's energy consumption. Roof is one of the main surfaces for absorbing sun heat. A part of the sunlight that radiating on the surface of the roof covers by traditional supplements such as bitumen, asphalt, water proof cover receives the energy and turn it to heat. A part of it reflects and a part of it emits into the inner parts of the building and impact the cooling and heating energy.

1-1 Research Background

The research on the "cool roof" started in the global cooling plan which is planned by the hot island department in environment energy's technology in national Lawrence Brocli laboratory and California university in 1980. In 1990 manufacturing the variable products in cool roof industry for domestic or industrial or commercial usage, had remarkably increased. In 2001 the products and the related factories won numerous prizes. Since 2001 achieving the cool roof prize is a standard for the prize LEED. Furthermore, for encouraging people, some countries like the US, dedicate financial credit for the families who are willing to use the cool roof in their houses. Since then a lot of researches and projects have done for reducing the disadvantages of the hot islands. To control wasting or receiving the heat through the school roof, is one of the approaches for energy optimization at schools. Due to the idea of using the cool roof can avoid emitting the unwanted heat through the roof.

2.Theoretical Framework

cool roof introduction, its advantages and disadvantages. Cool roof reflects the sunlight and keep the inner temperature stable. The roof is one of the main parts in a house, and as it covered a large surface, it has a major impact on energy consumption and temperature. It exposes to the sunlight and inter a lot of heat inside [1]. In urban districts almost 25% of the constructions made of roofs. As 90% of the roofs are dark they absorb heat and just 10% or 20% of the sunlight reflects. The temperature of dark roofs can rise up to 50 to 80 C. The cool roofs are made to decrease the disadvantages of the urban hot island. Instead of transferring heat into the house, it reflects the sun light and keep the temperature stable All in all, the cool roofs by reflecting and low thermal releasing, keep the temperature close to the surrounded environment and avoid the rise up in hot regions and waste heat in cold regions.

Tables 1: Types of cool roof [2].

Roofs with primer cool roof materials	**The roof supplement have reflection for example roofs like asphalt reflects 6 to 26%. while the white vinyl reflects 80% and 70% of heat.**
Cool roof covering	One of the ways to turn normal roof to cool roof is to use the cooling cover having the energy ticket.
Green roof	Cultivate plants on the roof

Factors involved in cool roof construction: the sunlight angle (which is related to: the shape or form of the roof latitude and the time length

- sunny or cloudy weather
- sunlight intensity regarding the quality and pollution of the atmosphere
- reflection coefficient
- the color, material, roof covering
- height (the air speed)
- the ceiling panel and its layers (building materials, covering, inner or outer covering)
- air circulation in double roofs

Tables 2: Types and Characteristics of Cool Roof Materials [3].

Characteristic	**Name**	**Material**
Combined layers made by organic wool or asphalt and fiber glass that used for places with high heat release or light. Upper layer made by silicon or color substances. There are manufactured hard panels with reflective covers ready to use.	Asphalt tufal	Roof material
In this case, the cooling liquid sprayed on the roof and after a while it becomes hard.	Foam roof	
As filling and joints in different colors	metal	

Natural bitumen with plastic and ampilified material layers and reflective covers	Modified natural bitumen	
Contains polymer transparent elements like acrylic and the color and the color substance like titanium dioxide that make the matt and reflective	White covering	Roof final coverin g
Covers with different colors reflective, mostly I light colors light lemon yellow	Coloring covering	
Aluminum covers that placed on the asphalt roofs.	Aluminum covering	
These materials are cheap and easy to use, they have variable shapes, color, texture that able to reflect the sunlight release the heat like bitumen layer	Tufal, board tile	
Construction elements that contains polymer substance such as bitumen hydrocarbon, industrial plastic like EPMD and polymer like PVC and poly Fenilin	Polymer plates	
Robber polymer pre made plates use for low or high slope, and place on the roof by specific glue.	Monolaye r covering	
Like EPDM and use the cement to fill the gaps	Flexible monolayer s covering	
Such as: PVC / TPO that they are flexible layers and made by polymer plastics. The heat melts the holes of a plate. they are reflective and have ampilified layers for longer maintenance.	Soft monolayer	
Light or dark colors to enhance the reflection and heat release use the different dark colors with new combinations.	Acrylic	Color

1-2 school buildings characteristics for using the cool roof

The energy consumption depends on numerous factors include:

- Air penetration and air circulation
- the difference between the uncontrolled outdoor temperature and controlled indoor temperature in different seasons
- the free received free energy in different seasons
- transferring heat ratio from the outer parts [4].

This is considered that the evaluation of effective variables on the outer parts of the buildings in transferring the heat is really important. The outer parts are all the surrounding surfaces such as; walls, ceiling, floor, opening doors and etc. that they connect the the controlled inner space to the uncontrolled outer space [5]. In spite of the residential buildings where 24/7 are in use, the school buildings are used partly 8hours a day. And they are mostly closed in summers [6]. As the schools are closed at nights, regarding the region the winter condition for schools is at 8:00 a.m as the coldest hours. (8:00 a.m to 10:00 a.m of the coldest month is the factor for defining the winter crisis condition) [6]. On the other stream the inner parts outweighed and it is considered as the dominant factor. In cold seasons, it helps that the majority of needed heat provides indoors, and by designing according to the region's climate, use the sun heat for heating inside the building. In addition, because of the roof large space in school buildings, the roof is under the exposure of the sunlight daylong and at nights reflect heat back to the cold sky, and harshly effect the temperature quality. By decreasing or increasing heating island, by absorbing or repelling the sun's heat have an important impact on heating or cooling expenses. The cool roof advantages are up to the geographical regions. therefor; using the cool roof in cold and mountainous zones lead to use more heating facilities. So, using the cool roof in hot regions with moderate winters is quite beneficial [7].

The cool roof benefits in school buildings:

- decrease building's heat absorption
- decrease the air circulation and cooling system expenses and better maintenance
- decrease the maintenance and longer lasting
- no need for renewing the roof and lessen the solid trash
- build the efficient and better-looking roofs
- decrease the negative effects of urban heating and global warming
- to level up the educational staff comfort
- ecosystem sustainability by turning the schools to green schools
- to save up 7to15% energy for summers [8].

2-2 Review on the history of the research

As a prove on the theory of the effective points of cool roof in thermal comfort and energy saving in educational buildings in hot regions, we peruse 3 international articles and one research in the U.S from the website "science direct" . The information have been collected 1998 to 2016. and on this website the details of the cool roof have been discussed, analyzed and presented. In research by A. Synnefa and others in 2012 assuming that the cool roof is a system that reflects the sunlight and away the sun heat from the surface of the roof and keep it cool. It was field tested in Greece . The school building located adjacent the Main Street in Kaisariani city near Athens, Greece. The school building consists of 2buildings built in 1980.This school has a rectangle plan and 2floors with a yard. There are 2classrooms and staff office in the ground floor. The roof area is about 410 meters square,and the whole area is about 939 meters square. The school building made by reinforced concrete which is not insulated.The windows recently replaced by double glazed windows.

Fig. 1: Location and view of the school building [9].

The insulated heating system (heating water by radiator) by natural gas (energy 100,000 kilo calories per hour). There is a fan in teachers' room which can be opened or closed and use the natural air circulation by opening the windows on off days. Lightening is provided by natural light and fluorescent lamps for each class used by 20 students (120 in total) in each classroom ,15 adults as staff. The set temperature for heating is 20C for classrooms and 18C for the office and corridors and for cooling is 26C. For this case the building plan, the building related data such as; cooling and heating, air circulation operation program, the number of people, and the bills were collected. The surface primer part covered by sand and cement. Sunlight reflection (SR) is 0.02 for a surface covered by gray concrete. The chosen cool roof technology is waterproof elastic which is measured in national university and Kapotsertini university in Athens.

Tables 3: Characteristics of applied roof covering [9].

SRI	Infrared sun reflects (SRNIR)	Visible sun reflects	Infrared reflections	SR Sun reflective
113	0\89	0\95	0\08	0\08

Sun reflection measured based on spectral reflection
For measuring the sun reflection and sun reflection indicator (SRI) the (ASTM G159-912standard and ASTM E1980-01 are considered.
The sun reflection ratio measured based on spectrum reflection.

The process includes cleaning up the roof and then apply a double layer cool roof cover. Supervision and data analysis done by using the building simulator software TRNSYS. To evaluate the thermal comfort and school building energy function before and after the cool roof covering the temperature data sensors and relative humidity are installed outside and inside the building. The sensors installed in 3classrooms (ground floor adjacent the ceiling), in teachers office and one in the outside. Also in certain days, temperature measurement with an infrared thermometer (infrared thermometer Kool and Palmer) And an infrared camera (IM 13-7.5 wave length, AGEMA them vision in the building ceiling. The measurement done between 9to 18). It's been done in same different points of the roof and set an average temperature the closest meteorology data are also collected from the closest meteorology station. The data include: hourly values from outside temperature, outside humidity, sunlight (the whole and partly), wind speed and orientation parameters. It's been measured before the cool roof installation in October 2007 and after it in 30th September 2009. The building model arranged by TRN build. The collected data

during the supervision and regional presented data of the outdoor climate are used as the input data. Calibration and model's arrangement done by consideration of turning off the energy system and with comparison of the indoor measured temperature and predicted indoor temperature As the building is consist of different parts with its own function, the different parts are divided in 11 parts.

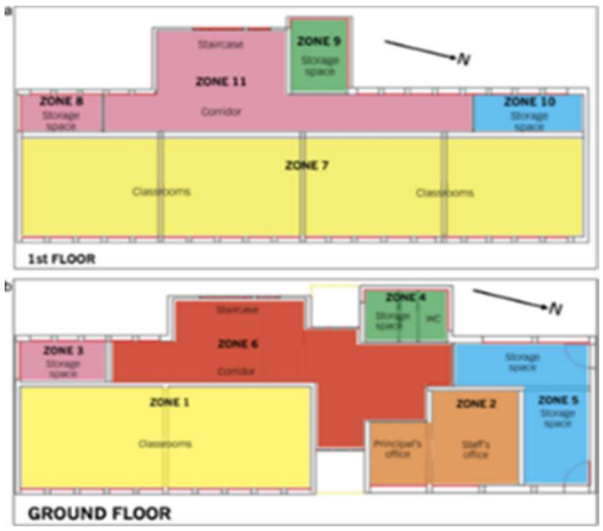

Fig. 2: School building zoning [10].

Estimation the effects of the cool roof on the energy load, it is assumed that the building is cooled up in summer and heated up in winter. The cool roof function is more effective for uninsulated buildings than insulated buildings. As it is expected, after using the cool roof covering the inner temperature will decrease. For cooling down the building in summer time this temperature rise will approximately get 3C for uninsulated buildings. This will be less effective for uninsulated buildings. For heating period (cold seasons) from October to April, the effects of cool roof will descend and temperature reduction after using the cool roof is not considerable in summertime.

Tables 4: Estimation of the effects of cool roof on energy load [9].

Cooling loads reduction 40% annually (3KWH per m)	**Cooling load**	**Uninsulated reference building**
Heating loads rising 10% annually (2.6 KWH per m)	Heating load	
Cooling loads reduction 35% (1 KWH per m)	Cooling load	Insulated building
Heating loads rising 4% (0.7 KWH per m)	Heating load	

For evaluation of effects of the cool roof covering on the surface temperature the hourly amount of surface temperature for a whole year for the reference building and the cool roof building is measured. After using the cool roof covering, there will be a remarkable reduction in surface's temperature. The analysis indicates that the temperature reduction in summer is about 20C. The other important aspect measured by the surface tempest analysis is that the daily temperature fluctuation for the reference building's roof is remarkably more. During summer time the average daily temperature fluctuation is about 20C but for the building covered by the cool roof is just 10C.

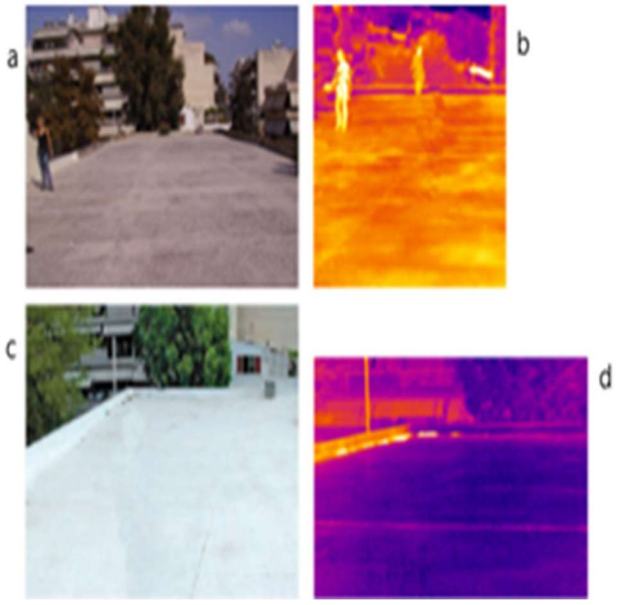

Fig. 3: The surface temperature of the roof measured using infrared camera before and after using a cool roof.

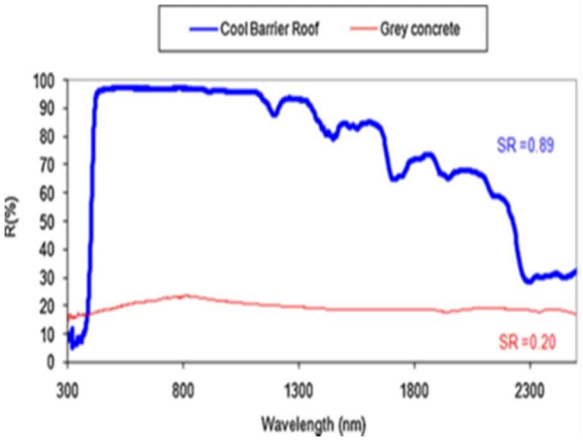

Fig. 4: Spectral reflection of the roof surface before (gray concrete SR=0.2) and after (AABOLIN cooling roof barrier SR=0.89) application of the roofs [9].

This technology is quite useful for European climate (especially Mediterranean). The cool roof function in educational buildings can be considerably effective for people's thermal comfort inside the building and make it functional for energy and increase the roof expectancy (life time).

Tables 5: Air temperature reduction after using a cool roof for the area adjacent to the roof [9].

Average 1.8	**Maximum 2.8**	**Minimum 0.8**	**Cold seasons**	**Uninsulated building**
Average 0.9	Maximum 1.2	Minimum 0.9	Hot seasons	
Average 0.5	Maximum 0.7	Minimum 0.3	Cold seasons	Insulated building
Average 0.4	Maximum 0.9	Minimum 0.2	Hot seasons	

The other research have done by A.V and others in 2015 to show the effects of the cool roof on the heating energy function in school buildings as a field test and number analysis The buildings as the case study, they are next to each other, which one of them is the reference building and the other one is the building covered by the cool roof.

Fig. 4: Reference Building and Tested Building [11].

This building is an elementary school located in Agaleo (latitude N38:00 longitude: E23.47) in Mediterranean, with hot summers. This building includes: ground floor and some blocks, the roof covers by asphalt. According to the insulation studies the building insulated by rock wool. As far as it it concerned with the transparent surface, most of the rooms have regular and brightening windows. The reference building has double glazed window (9m.m space) with aluminum frame width 0.06m.m. however the windows in the second school have aluminum frame and they aren't double glazed and the width is 0.06m.m. The classroom doors are wooden, except the chemistry room. the research plan is from 7:30 to 11:30 on workdays. The experiment done in the sunny sky and temperature 18.6 to 36.6C and the average rate of temperature was about 27.8.

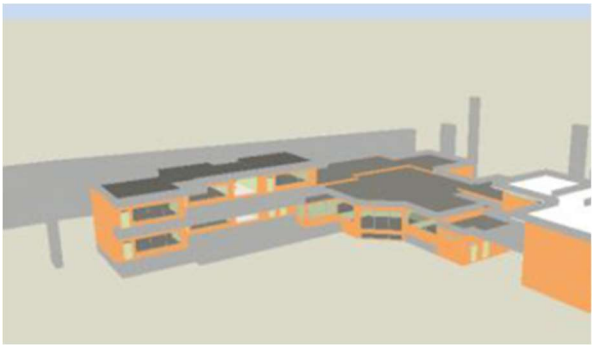

Fig. 5: The location of the cool roof of the north and southeast classroom the northern staircase and the classroom adjacent to the northern staircase [11].

The cool roof installed in northern and southeast classrooms, northern staircase. The classroom adjacent to the northern staircase. The cool roof covering with heat release 0.89 and heat reflection

0.89. Thermal conductivity 0.87 w/mk and the area 265 m squares have done in June the 10th 2015. The data was collected 2weeks after and before the cool roof covering installation. they install 8 sensors inside the building, 2 sensors for measuring the temperature the outer parts of the roof, 2 sensors for measuring the surface of the roof 2 sensors for measuring the average humid inside the room, other 8 sensors are inside the building which is covered by the cool roof at the same points at the reference building. The simulations made by design builder V.4.2 software on a personal computer 64 bits windows CPU 3.4 GH RAM 8 and the time for the measurement is 20 minutes.

The standards include:

Local climate data, the outer parts of the building material according to the defined material patterns, the heating and cooling and air circulation system specification. The national technical instruction TOTEE 20701-18, air circulation (temperature set on 26C -rarely use of ceiling fan when the temperature is over 29C). The equipment and lightening loads are in the national technical instruction TOTEE 20701-1, and sunlight path diagram and sunlight range. The results indicates that 10 days after using the cool roof the daily average of inner temperature under the cool roof is respectively 1.3-2.3C and 1.6-1.9C. After using the cool roof, the usage of the ceiling fan and the air circulation system respectively 30% and 20% electricity saving. The cooling loads in summer reduced 30% and the heating loads in winter increases 12% that if the air circulation. system uses instead of the ceiling fan it will compensate. (even for the whole building) The temperature difference in the spaces with or without the cool roof in the reference school is 15C and also the average temperature difference is 5.5C. The cool roof is a beneficial solution for school building in Greece. Overall it leads to primer energy saving and because of the temperature reduction leads to improve the thermal comfort. To evaluate Athens climate condition, the meteorological statics of Athens received as an EPW file on international meteorological website WMO and analyzed by the "climate consultant" software. As it demonstrated on table/diagram 5, this city is a coastal city with low mountains and hot and humid summers and moderate winters. In summer days the temperature is about 34C and sometimes humid. The winters are moderate, no icing and temperature don't arise below 5C. According to the Athens climate, because of the hot weather in summers and moderate winters in these 2researches,it is evaluated and resulted that the cool roof covering is useful in this city.

Climate data for Downtown Athens (1991–2020), Extremes (1890–present) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	22.6 (72.7)	25.3 (77.5)	28.9 (84.0)	32.2 (90.0)	38.4 (101.1)	44.8 (112.6)	43.0 (109.4)	42.6 (108.7)	38.6 (101.5)	36.5 (97.7)	30.5 (86.9)	22.9 (73.2)	44.8 (112.6)
Average high °C (°F)	13.3 (55.9)	14.2 (57.6)	17.0 (62.6)	21.1 (70.0)	26.5 (79.7)	31.6 (88.9)	34.3 (93.7)	34.3 (93.7)	29.6 (85.3)	24.4 (75.9)	18.9 (66.0)	14.4 (57.9)	23.3 (73.9)
Daily mean °C (°F)	10.2 (50.4)	10.8 (51.4)	13.1 (55.6)	16.7 (62.1)	21.8 (71.2)	26.8 (79.9)	29.3 (84.7)	29.4 (84.9)	25.0 (77.0)	20.3 (68.5)	15.6 (60.1)	11.6 (52.9)	19.2 (66.6)
Average low °C (°F)	7.1 (44.8)	7.3 (45.1)	9.2 (48.6)	12.3 (54.1)	17.0 (62.6)	21.8 (70.9)	24.2 (75.6)	24.4 (75.9)	20.4 (68.7)	16.2 (61.2)	12.2 (54.0)	8.7 (47.7)	15.0 (59.0)
Record low °C (°F)	−6.5 (20.3)	−5.7 (21.7)	−2.6 (27.3)	1.7 (35.1)	6.2 (43.2)	11.8 (53.2)	16 (61)	15.5 (59.9)	8.9 (48.0)	5.9 (42.6)	−1.1 (30.0)	−4.0 (24.8)	−6.5 (20.3)
Average rainfall mm (inches)	55.6 (2.19)	44.4 (1.75)	45.6 (1.80)	27.6 (1.09)	20.7 (0.81)	11.6 (0.46)	10.7 (0.42)	5.4 (0.21)	25.8 (1.02)	38.6 (1.52)	70.8 (2.79)	76.3 (3.00)	433.1 (17.06)
Average relative humidity (%)	72.0	70.0	66.0	60.0	56.0	50.0	42.0	47.0	57.0	66.0	72.0	73.0	60.9

Source 1: Cosmos, scientific magazine of the National Observatory of Athens[69]

Source 2: Meteoclub[70][71]

Climate data for Elliniko, Athens (1955–2010), Extremes (1961–present) [show]

Climate data for Nea Filadelfia, Athens (1955–2010) [show]

Fig. 6: Review of Climate Information of Athens.

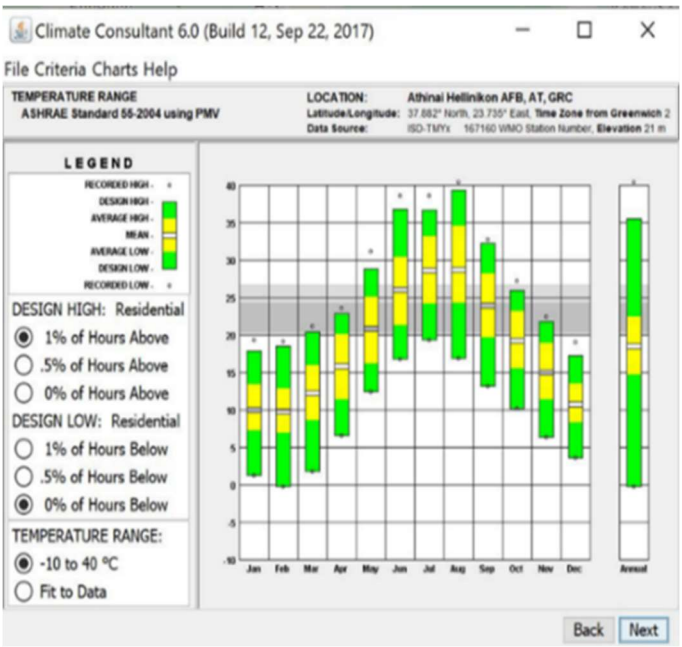

Fig. 7: Chart of Annual Air Temperature Changes.

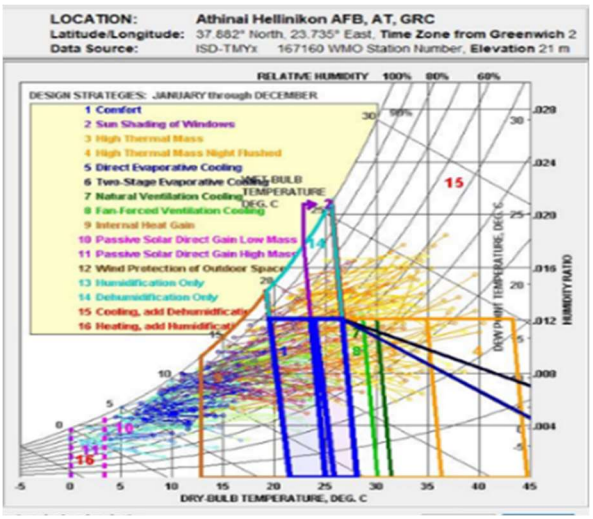

Fig. 8: Psychometric Chart from Climate Consultant Software and Ashrae55 Thermal Model.

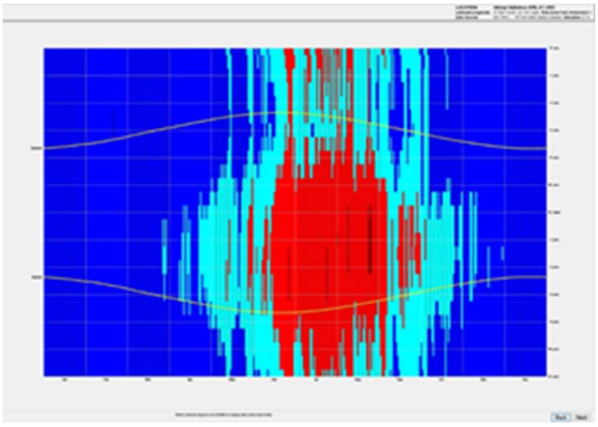

Fig. 9: Annual Climate Calendar.

Fig. 10: Geographical location and elevation profile of Athens.

A research have done by H. Akbari and others in 1998, for studying the use of cool roof at schools in 11 states in the U.S. Simulation method on DOE-2 based on use estimation of inner loads and air circulation and cooling and heating in 11 residential buildings, offices, stores, educational buildings, healthcare (hospital and retirement home),food stores and money saving estimations have done by checking the roofs in the U.S. It is reported that the average commercial and residential building's roof. The roofs in Atlanta are the brightest in color and Philadelphia has the darkest roofs. Which means the roofs get darker from south to north. The average buildings Albdo range in all the buildings is 0.25 which used as the input data for the simulation energy models. The ceiling Albdo average rate in residential or commercial (Atlanta and Philadelphia) stems from the analysis and evaluation of space pictures. The energy saving rate measured by cool roof simulation. It becomes clear that the most energy saving in buildings happened in hottest and sunniest cities. By getting cold this energy saving will reduce.

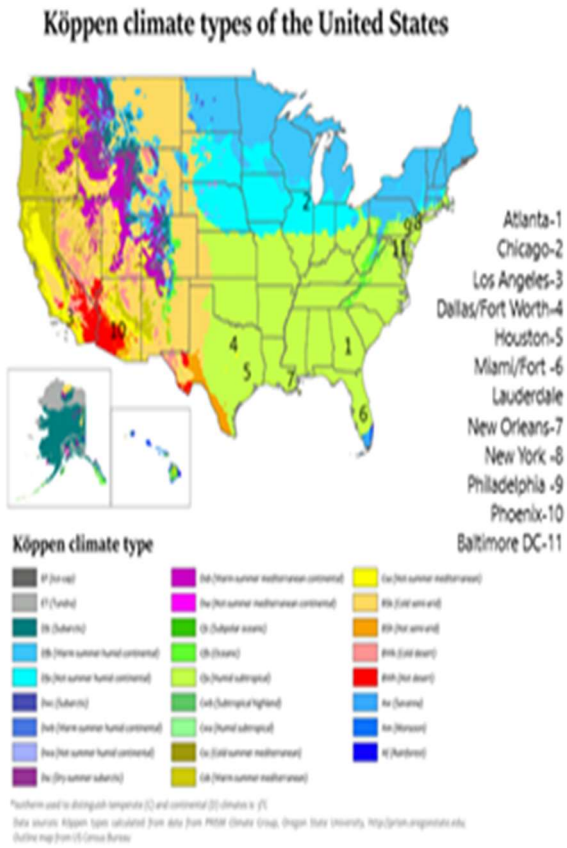

Fig. 11: Climate division of the United States of America based on the coupon and the studies cities [12].

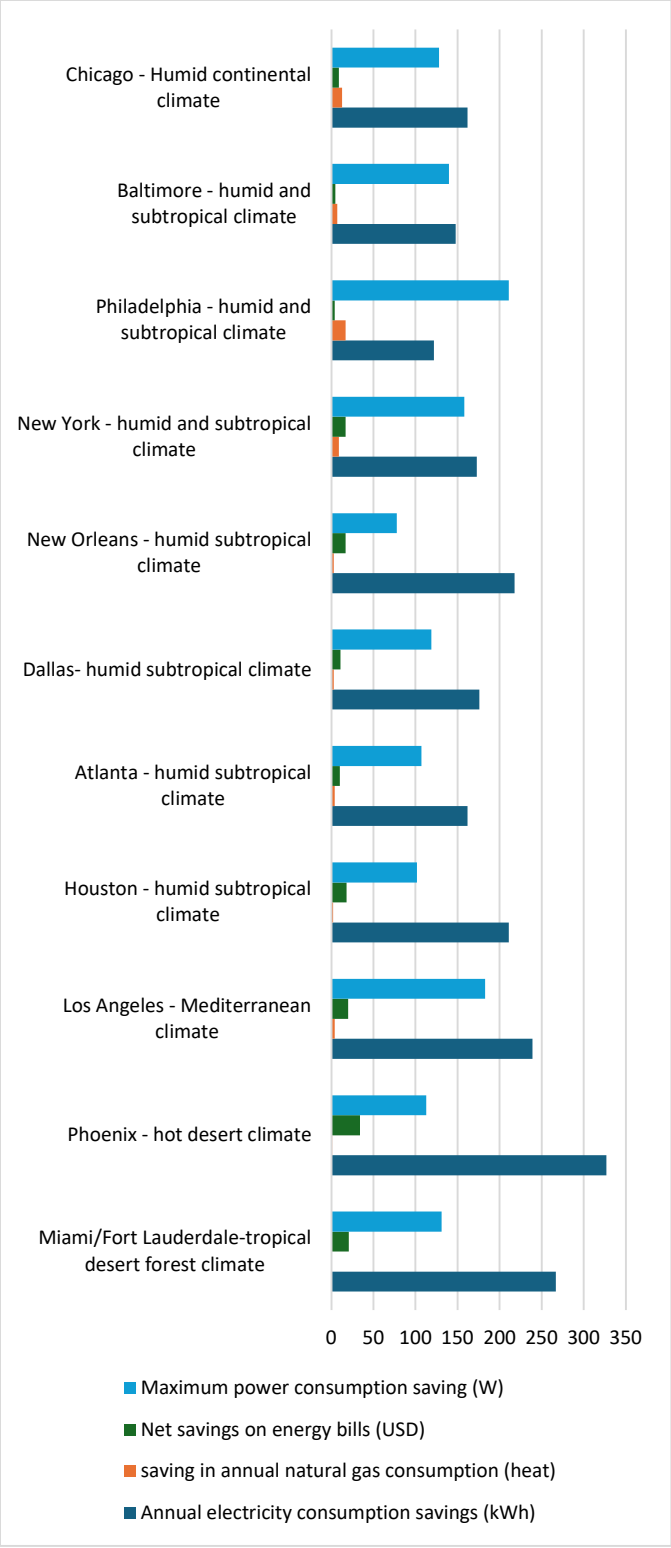

Fig. 12: Estimated saving per 1000 square feet of air conditioned building roof area resulting from the use of high-albedo roofs in residential and commercial buildings in 11 metropolitan statical areas in the united states [13].

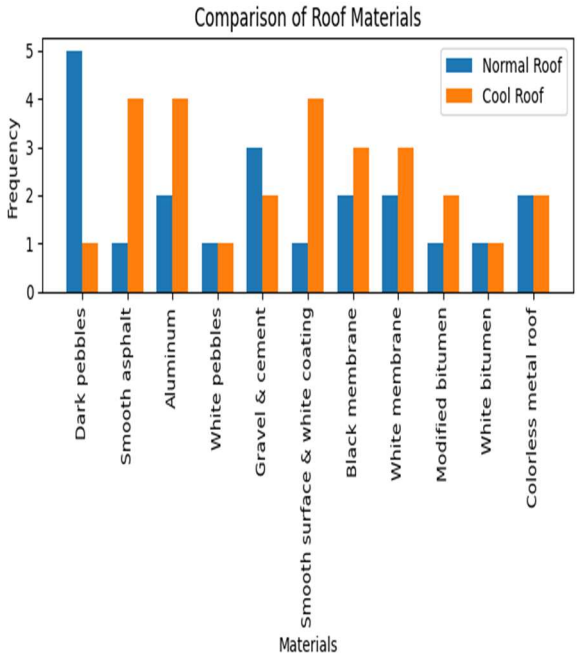

Fig. 13: Authors with software R.

The energy saving in each square foot multiplied in population. When all the results scaled in the U.S, it is realized that using the roof with high Albdo leads to save up the annual energy usage and the maximum demand that the highest rate belongs to the cities in hot dessert climates and hot forest jungles. If the e current roofs replaced by the reflective roofs, the energy saving is about 750 million dollars and the reduction in demands in most of the hottest regions in the country equals not running the 13 powerhouse (capacity 0.5 GW) and about 15% of the northern cool New York and population Chicago. Reported saving here probably is less than the estimation, because DOE-2 model in this simulation generally underestimated. By improvement in DOE-2, estimation can be more accurate. Levinson and others in 2005 have done research bringing forward utilizing the building in California for the office store buildings, health care buildings, schools and the universities [14]. Based on recommendations the slope cool roof functions details presented for cooling energy using reduction and as a result reduction in electricity use. In this research after the study on the amount of receiving sunlight's energy, we compare the cool roof and a normal roof and by expressing the environmental positive or negative effects of the cool roof, and present the standard. In this article, this is resulted that the cool roof covering can reduce the need of roof insulation, cooling system and air circulation system.

Tables 6: Comparison of cool roof structure and normal sloping roof [15].

Cold roof with low slope	A normal roof with a low slope
The roof is made of white pebbles	The roof is made of dark pebbles
The roof is made of gravel and cement	Roof made with smooth asphalt surface
Roof with smooth surface and white coating	The roof is made of aluminum
White single-layer membrane (EPDM, CPE, CSPE, PVC)	Black single-layer membrane (EPDM, CPE, CSPE, PVC)
Modified bitumen white coating on mineral surface (SBS, APP)	Modified bitumen with mineral plate coating (SBS, APP)
White painted metal roof	Colorless, corrugated metal roof Dark color metal roof, wavy
White asphalt coating	Black and brown asphalt coating
Liquid applied coating white off-white rough white	Liquid applied coating flat black
White concrete tile off-white	Red concrete tile
White clay tile	Red clay tile
White cement fiber tile	Unpainted cement fiber tile

The cool roof environmental effects:

- increase the thermal comfort, reduction on carbon release, decrease the cities heat island in summer
- The cool roof release less heat out of the outer parts in comparison of a normal roof.
- environmental atmosphere temperature leading to reduce the Ozone layer intensity.
- Save up the electricity
- The cool roof last longer because of the reduced thermal split, so there will be less trash need of pollution sites

If a building cools up by the electricity and heat up by the natural gas burned locally, the cool roof may cause to increase the natural gas use, even though it decreases the annual energy usage. For the times in a year which the roof need annual cleaning the certain amount of water and cleaning products. Using the drinking water for cleaning may be a threat for California frequent droughts and also the cleaning products pollute the underground water. The solution here is to clean up the roofs by cleaning products and neutralizing the acid polluters with high pressure water (c=m2 7/5) and baking soda (g/m2 2.4)

4. Research Methodology

The current research as an analytic review on study the former researches about cool roof in the school all around the world. The research method evaluates in cool roof field in the educational buildings in hot climates and by indicating the climates diagram in regions, executed the cool roof express the similarities to the climates in Iran and by reviewing the documents method and imply the information from valid Iranian or foreign websites for conclusion.

5.Results and Discussion

By reviewing the researches out the cool roof in educational buildings, it is concluded that the cool roof technology in hot and not very cold climates is quite efficient for energy saving and thermal comfort for students and by implying on the importance economics in educational building, it is resulted that it will be beneficial in building expenses. Our country, Iran has a diverse regional climate and by consideration the regional climate can be effective in designing sustained educational buildings. As the schools are closed at nights based on regional climate by Morteza kayamarzi. The winter condition the coldest hour which is 8:00 a.m (8:00 am to 10 am in coldest month is criterion the harsh winter condition). From the results of 2 researches in Greece and in the U.S this is concluded that the cool roof in the hot climate and moderate winter will be an effective approach in hot regions also it is expected that the cool roof for school can help to reduce the cooling expenses for schools. On the other stream the researches indicate that the cool roof not necessarily be beneficial and the cold winter neutralize the cool roof effects on the other hand the cool roof covering is more effective for moderate winters region like the southern parts of Iran. It is currently concluded that the school buildings

in hot regions in Iran which have moderate winters the cool roof covering can cause the energy saving however using the cool roof in variable climates need more research and study. the point for reviewing climate regions can indicate to the summer's hot weather and winter cold weather from one side and the sunlight intensity. the studies about the cool roof in this article for the regions with hot summers and moderate winters and not included very cold winter.

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