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DAYLIGHT REFINEMENT OF A TRADITIONAL BUILDING IN HEBRON, PALESTINE

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ABSTRACT
The old city of Hebron suffers from population migration for several reasons. The most influential reason is the occupation rules against Palestinian people who are living there. Where these rules push them for the displacement, in order to take over their homes. Hebron municipality tried to encourage people to stay there by decreasing the taxes and providing them by nearly free electricity and water services. While physically, the historical buildings need to be renovated environmentally to fit the people's needs, taking daylight, ventilation and thermal performance and other factors into consideration. Accordingly, this research aims to study the possibility of enhancing daylight inside buildings there, as the daylight is an important environmental factor for living inside homes. A historical building was randomly selected as a case study to be surveyed, analyzed, and simulated considering the natural lighting passage inside it, to know to what extent the daylight level can be improved. On-site measurements and a simulation software (Dialux evo 9.1) were used to test different passive strategies of daylight refinement. The results confirm the high performance of lighting pipe over a skylight if it is used in the case study. Using such passive strategy was effective as a solution to improve the indoor environment of the traditional building, which can be adopted as a common strategy in other historical buildings of Palestine.
Keywords: Traditional Buildings, Daylight, Passive Strategies, Refinement.

1. INTRODUCTION

The old city of Hebron lies to the southeast part of the city, it is one of the best-preserved cities which goes back to the Mamluk period (1250-1517) and the Othman period (1517-1917). Its tissue is compact blocks of housing complexes built of thick stone walls with vaulted superstructures connected by covered passages, courtyards, and narrow alleys with small windows to street (Assi, Eman, 2011). Since 1967 till 1990 the city witnessed a great abandonment from the citizens because of political, social, economic and environmental problems and the city became semi empty (Sellick, Patricia,1994).

Despite the great enhancements which were done by the Hebron rehabilitation committee (HRC)to improve the conditions in the old city, citizens are still struggling with a serious problem in the indoor comfort conditions which make living hard in the old city. One of the factors that influence this problem is the lack of daylight in most spaces of traditional buildings.

In most rooms, the natural light is absent or insufficient, where the windows on the perimeter walls are not able to illuminate the whole environment being too small or too distant from the center of the room. This caused an increase in humidity and emergence of mold leading to serious construction problems. Beside that absence of natural light, make residents facing serious health and psychological problems (Wong, Ing Lian, 2017).

Moreover, full reliance on artificial lighting to provide sufficient lighting inside the rooms during the daytime increases the energy consumption in buildings that already covers about 40% of the total energy consumed worldwide (Xiujie,'et al', 2019).

2. RESEARCH BACKGROUND

Daylighting provides excellent lighting conditions for the interior spaces of buildings and saves energy by reducing use of electrical lighting. Furthermore, daylighting helps satisfy the human need for natural light, which promotes various health and performance benefits. Buildings that are naturally lit are more comfortable for human occupation. Daylighting makes people feel good about their environment and improves performance and morale. Daylighting will have a positive influence on operating income which offers the greatest single opportunity to affect savings, profitability, and rate of return. (Katz,'et al', 2005)

Passive techniques of daylight have a very good impact on enhancing internal environments. Beside windows; which considered as potential passive daylight technique for all types of buildings since the past; skylights were used to enable natural light from the sun to pass through roofs or horizontal surfaces of building interiors with limited openings from walls. (K. Al-Obaidin, 'et al', 2014).

- Skylight glazing is usually glass or acrylic material
- The size of skylight significantly affects the illumination level and heat leakage to the space below.
- The position of skylight plays an important role to maximize daylighting and/or passive solar heating potential.
- skylights may have adverse effects in terms of unwanted solar heat gain during period of summers and heat leakage during winters. (A. S. Azad and D. Rakshit,2018)

alongside windows and skylights, there are several passive methods to enhance daylight in a specific space.Every device for carrying daylight into a building has three components: a collector, on which daylight falls and which may be designed to receive light from specific directions; a channel, which carries the light through the fabric of the building; and a distributor, which emits the light in the interior.

Light shelves are a passive technique that enhance day lighting from windows by placing a horizontal reflective surface outside the window. It has three main components: a window, an inside shelf and outside shelf. The inside shelf reflects the all-transmitted light from the window onto the room ceiling. The outside shelf reflects the incident light upward to illuminate the room ceiling. (A. S. Azad and D. Rakshit,2018).

Light pipes (mirror light pipe (MLP) or tubular daylight guidance system (TDGS)) have been chosen to be implemented in the focused area. Light pipes are modern, but passive techniques which utilizes the daylight to illuminate the interior space of the buildings. It works on the principle of propagation of light from ambient to indoor due to multi-reflections on high reflective internal surfaces. Light pipes mainly have three components: the receiving part (hemispherical dome) in which sunlight gets collected, the received light goes to multi-reflections through the reflecting tube, and the lower part (diffuser) is responsible for uniform distribution of light throughout the space (Azad,2018,p.379).

- Light pipe utilizes about two-third of the available global illuminance in a clear sky day.
- It can reduce the problem of glare and would give daylight of better uniformity.
- Light pipe transmits both direct and diffuse light by multi-reflection mechanism (Tregenza & Wilson,(2017), pp 179).
- Scientists estimate electric lighting savings for the residential sector taking into consideration a non-working residential couple who spend a considerable amount of time at home with 300 mm diameter passive TDGS of about 390 kWh per year (C. Ciugudeanu and D. Beu, 2016).

3. RESEARCH OBJECTIVES

The main objective of this research is to determine passive daylight techniques that could be implemented in traditional buildings in the old cities of Palestine to enhance indoor comfort conditions. In order to achieve the main objective, group of goals will be achieved too, such as:

- Adopting passive techniques for daylight transport in traditional buildings.
- Improving the human activity which relate to the presence of the natural light.
- Decreasing energy consumptions in buildings by reducing the use of artificial lighting during the day time.

4. METHODOLOGY

This research is both quantitative and qualitative in its type, where the methodology consists of six phases based on the data collection method and simulation tool, as clarified in the following table:

Table (1): Research methodology phases

Phase1	Research background	• Passive Techniques of Daylight
Phase2	Data collection-surveys	• Weather Data • Built up characteristics • room index and grid measurement • Data tables and graphs. • Determine the daylight and humidity in the case study.
Phase3	Simulation and Virtual Model	• Virtual Model for the case study (class2) • Simulation and validation to current situation (DIALux Evo 9.1) • Simulation after integrating passive techniques
Phase4	Result	• Enhancing daylight results in traditional old city
Phase5	Analysis	• Analyzing the outputs.
Phase6	Conclusions & Recommendations	• Adopting techniques to improve natural lighting in the old city.

5. THE CASE STUDY: AMER BUILDING

To enhance the daylight, a traditional building was randomly selected as a study case; "Amer Buildings School" which is located within the old city of Hebron in Palestine. Here, the natural lighting should be increased in order to enhance the building environmental performance, as it is necessary for such educational buildings.

The indoor environmental conditions of buildings depend highly on outdoor climatic conditions. In Hebron, the summer is long, relatively hot with a clear sky, the winter is relatively cold and has s mostly clear sky. Over the course of the year, the temperature typically varies from 4C to 29C and is rarely below 0 C or above 32 C. The readings were taken on the twelfths of NOV. 2020 at 9:00-11:00 am. With clear sky conditions and a temperature around 21 C (weather spark).

The aim of the rehabilitation of Amer buildings was to improve the living conditions of residents in the old city by providing educational services through the rehabilitation of historic buildings (Fig.1-Fig.2).

Amer buildings were adapted into an elementary school for the children of the old town; the project was preplanned in the 2015- 2040 master plan under the educational projects.

Table (3): Class selection considerations

Room location	Location: first ground floor, second floor ... etc.
	Overlooking the courtyard
Roof type	Cross vaulted
	Domed Roofs
	Horizontal roof
Room envelope	Linked with neighbors' homes
	Overlooking outside courtyards
	Overlooking narrow streets, covered alleys covered passages
Roof level	Roof level in relation to adjacent one
	Overlapping of the interfaces
Recorded readings	Readings for natural lighting
	Readings for natural lighting integrated with artificial lighting

More than 30 abandoned rooms and open yards were rehabilitated to fit the new needs. The project was completed in July 2018 by the Swedish cooperation agency (SIDA) through the UNESCO Ramallah office (HRC Archive). A visit was arranged to the school in order to analyze the current situation and take some readings of lighting and ventilation in the classrooms. A number of considerations have been taken to choose one class room for the simulation optimization study (table3).

5.1. Data Collection

Two types of calibrations were carried out:

- Light-meter: to detect the daylight
- Temperature and humidity meter and WBT. Dew point: to test humidity

The measurements helped to set the guidelines to develop the simulation stage. The study obtained data from the instruments in a specific period under the same conditions that contributed as a reference to graph and virtual model. The calibration targeted the preliminary stage of the experiment to monitor indoor daylight and humidity. Then a virtual model for a chosen classroom (class 2) was developed with the help of the Design-Builder and DIALux software. The simulation model considered the climatic information of the site and properties of the selected materials, in order to validate the outcomes of the virtual model.

Amer buildings -a rehabilitated traditional building in the old city of Hebron which were converted to primary school- was taken as a case study for data collection about traditional buildings daylighting for simulation stage.

A visit to HRC (Hebron rehabilitation center) was made in order to have building plans. Amer building consists of three floors with five entrances and about fifty rooms. A visit was done for the school, and activities conformity for the plans according to real space occupancy was performed. Beside the administration spaces, a library and labs, there were seven classes distributed in the first and second floor (four classes in the first floor, two in the second and one in the middle level).

After taking classes' dimensions and asses conditions of each class: daylight availability Window to wall ratio, artificial light availability, interior surfaces (surface color's, reflectance, clean or dirty), weather conditions, courtyards, etc, a grid map plan was drawn for each point to take reading correctly for the seven-classes. The minimum number of grid measurements points decided by calculating Index room.

Table (4): Determination of measurement points (Hajibabaei, et. al., 2014).

Room index (R)	Minimum number of measurement points
Below 1	9
1 and below 2	18
2 and below 3	25
3 and above	36

Room Index = (Space Length*Space Width/ ((Space Height -Working Plane) *(Space Length + Space Width)).

The working plane is assumed at a distance of 0.60 m from the floor (for children desktop height) (Neufert). For average, class area was (5.4m*4.3m*3.1 m), the derived room index "R" is 0.95, according to table (4) (Hajibabaei, 'et al',2014) the minimum number of points is 9 with a measuring grid size of approximately 1.35 by 1.15 m.

The measurement points were identified, and nomenclature was assigned to detect the position of each instrument. At each point, two readings were taken for the daylight illuminance and illuminance from daylight with artificial light on. A humidity reading was taken for each classroom. The readings entered to Excel-sheet (Fig.3) to find the average of readings to determine the critical classroom (the case).

Daylight measurements were conducted with a digital lightmeter (A lightmeter is an instrument indicating the illuminance at the point of measurement). On date near the winter (12 NOV 2020), at 09:00-10:30 am. At the desk top (the work plan 0.60) while windows and openings are not covered and the electric lighting is switched OFF (study the performance of daylighting). Other measurements were taken while windows and openings are not covered and the electric lighting is switched ON (study the performance of combined electric lighting and daylighting). Digital photos were taken for each class.

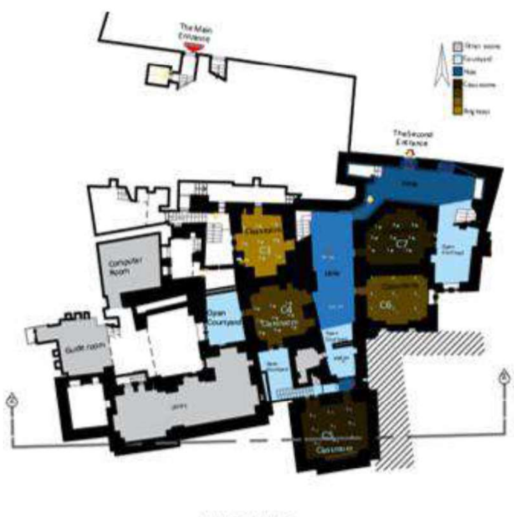

Figure 1: Amer Buildings - ground floor

Figure (2): Amer Buildings - first floor

The daylight level entering the traditional houses mainly depends on the area and the number of openings in each space, their orientations, their distribution on one or more walls, their connection to the courtyard (roofed or not), and wall thickness.

The average measured daylight intensities with the artificial light was around 100 lux, which is insufficient according to class activity ranges (300 lux) (code for lighting, CIBSE, 1994). The first floor of the buildings has insufficient daylight because of the few and small openings overlooking to a narrow corridors and alleys with high wall in addition to roofed courtyard which all prevent sunlight to enter. Regardless of the orientation of the windows most classes spaces are completely deprived of natural light (less than 40 lux). In the spaces of the upper story, daylighting conditions are improved according to direct connection to an open courtyard, which enhance the daylight entered through the windows overlooking it. Despite this, significant variations were found depending on the orientation and the number of the windows. In the north-facing class, only restricted areas, which are found in the immediate vicinity of the windows, have sufficient daylight (over 120 lux) with an average of 54lux, whereas the northeast-facing class has amore sufficient daylight (with an average of 120 lux), (Fig.1,2).

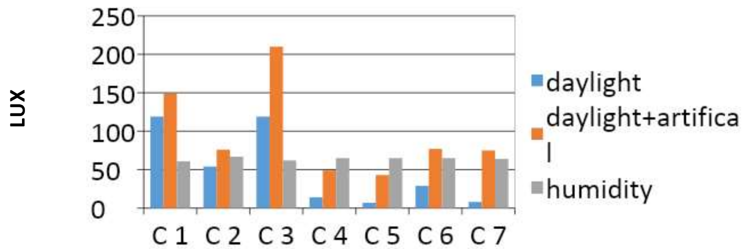

Figure 3: Average Readings for the seven classrooms in Amer Buildings School internal illuminances by Light meter (C2 the case study).

Classroom 2 (C2) was chosen as the experimental space. classroom 2 located on the south-east side of Amer Buildings at second floor. classroom 2 measures of 5.40m (width) by 4.30 m (depth), with a clearance floor-to-ceiling height 2.40m to 3.10m. The wall thickness measures about 0.80m with the north-wall overlooking the courtyard while the other three walls are adjacent to neighbors and closed. The aim was to study the difference between the classroom with ` the presence situation and the classroom with suggested passive daylight enhancement techniques. Figure 4 illustrates the class2 space “base case” architectural parameters.

Despite class location, it has north- windows. The class has two identical north windows beside each other making a unit. Each window measures 0.55m (width) by 1.00 m (height) and 0.40m from the floor. The walls of the room were covered by a white paint and the ceiling with beige paint while the floor was covered ceramic brown tiles. As graphs show (Fig.3) an average internal illuminance of 54 lux. Only the immediate vicinity of the windows has sufficient daylight (over 120 lux).

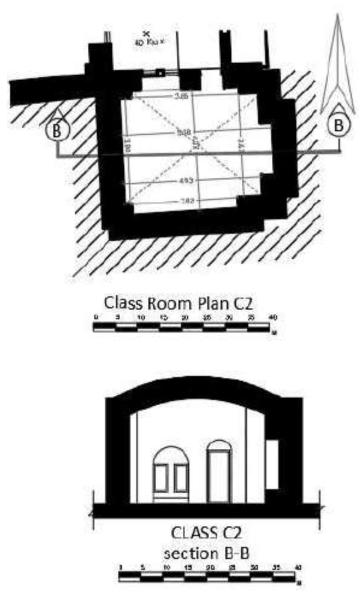

Fig.4 plan and section with for class room"2"

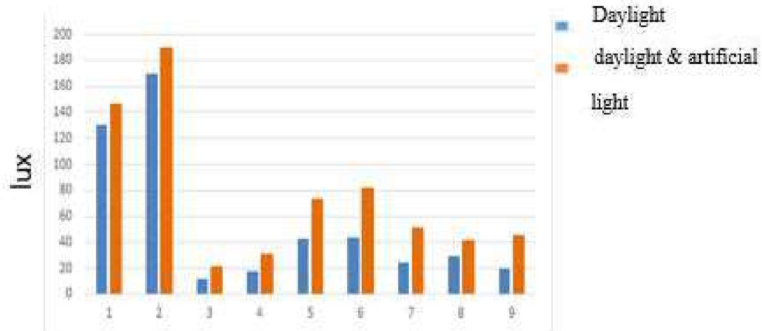

Figure 5: Readings of internal illumination of classroom 2 by light- meter.

6. SIMULATION AND VIRTUAL MODEL VALIDATION

DIALux is a software developed by DIAL for professional light planning, which beside the artificial lighting systems, includes some conventional daylight systems such as windows and skylights. (Ciugudeanu, Beu, 2016).

A virtual model was developed for classroom 2. The model considers the location and the orientation of the case study (C2) correctly. In order to make the model simulation more realistic, true materials of the building from Dialux library were applied on the 3D model. The data from equipment placed in the classroom2 was compared to the results obtained by the simulation. The results of validation showed that outputs from the virtual model (51.6 lux) (Fig6) have a good agreement with the conditions of the real collected data (54 lux).

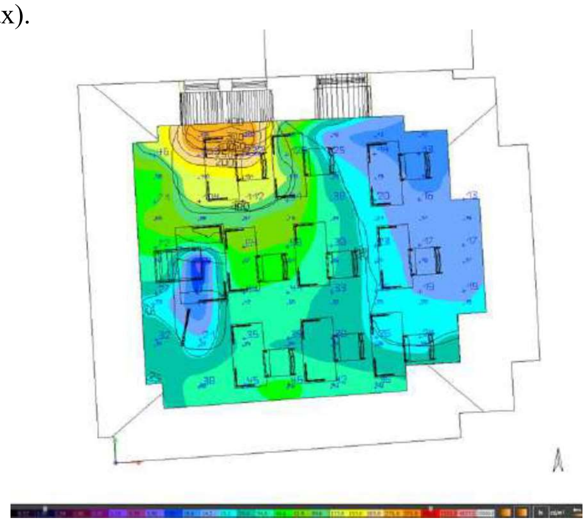

Figure 6: Utilization profile: Educational premises - Educational buildings, Classroom

(Notes on planning: Daylight proportion for Clear sky (Direct sunlight) on 12/11/2020 at 09:10 AM (Jerusalem Standard Time). The ambient conditions for classroom"2" are clean. Ground area: 22.85 m² | Reflection factors: Ceiling: 70.7 %, Walls: 75.8 %, Floor: 42.1 % | Maintenance factor: 0.80 (fixed) | Clearance height: 2.381 m - 3.100 m |. work plan height:0.60 cm).

Optimizing the internal daylight was done by two phases:

- optimizing the internal environment by improving materials to lighter and more reflective ones; walls and ceiling paintings from beige to white, floor tiles from brown to white, and changing the metallic door to glassed one. suggested optimizations integrated with the second phase to reach the final results of enhancements.

- second phase was in two stages; first two skylights with 60cm*60cm dimensions were integrated to the virtual model. the location and the size of the skylight influence the amount of entered light. Reflective material was added to skylight in order to increase its efficiency and transmissions of light. The east and south orientation was chosen based on the occupancy time of the space.

The second stage was integrating a light pipe model to the virtual model. Due to the lack of a light pipe model to be included in the Dialux evo software, a search for light pipe specifications suitable for illuminating the case study area from one of the manufacturers of light pipes. Referring to light way company's tables (www.lightway.cz, 16 Dec 2020). The type of lighting crystal 600 HP was found to be corresponding to the classroom area. referring to the specifications of this type, it was found that it gives a 280 lux in winter over casted sky and needed an 0.50 dim aperture (www.lightway.cz, 16 Dec 2020) (Appendix). going back to the Dialux evo and looking for an artificial lighting unit with a diameter appropriate to the previous specifications, AURA light "36wat dim 19 inches" was adopted (https://lumsearch.com, 16 Dec 2020), and the intensity of its lighting was modified to give the same intensity of the light pipe and then included in the model and simulated.

7. RESULTS AND ANALYSIS

The results revealed a great enhancement in lighting internal spaces of traditional buildings. keeping up the same conditions of the actual readings (clear sky), the simulation revealed a 100% enhancement of the required illuminance level in the classroom "the case study" and 87% in overcast conditions.

referring to light shelves, the big depth of the walls (0.8 cm), windows inside sill act as inside light shelf for the classroom allowing for greater penetration into the classroom and this is a good point for daylight in traditional buildings envelope.

results of basic reasonable changes such as making lighter and more reflective walls and ceiling paints, lighter and reflective floor tiles and changing the door to a glass one, enhanced the illuminance of internal space by 14%. from (51.6 lux to 93.8 lux) (Fig.7)

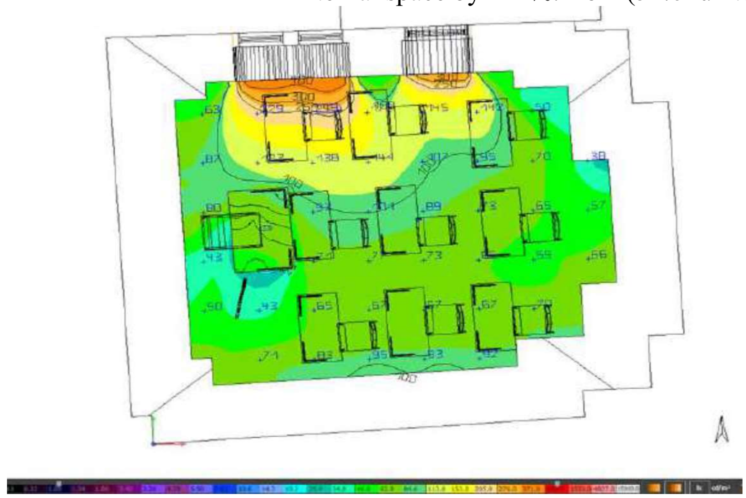

Figure 7: Contour diagram for classroom"2" optimization by adding
Ground area: 22.85 m² | Reflection factors: Ceiling: 75.8 %, Walls: 75.8 %, Floor: 60.8 % | Maintenance factor: 0.80 (fixed) | Clearance height: 2.381 m - 3.100 m | work plan height:0.6cm.

Two passive daylight techniques had been applied to the virtual model in Dialux evo and simulated which are:

- Skylights improved the internal light conditions about 9% (93.8lux to 122 lux) (Fig.8).
- Light pipe improved the internal light conditions about 70 % in minimum (93.8lux to 304lux) in clear sky (reading condition) (Fig.9)

Figure 8: Contour diagram for classroom"2" optimization by adding two skylights (93.8lux to 122 lux)

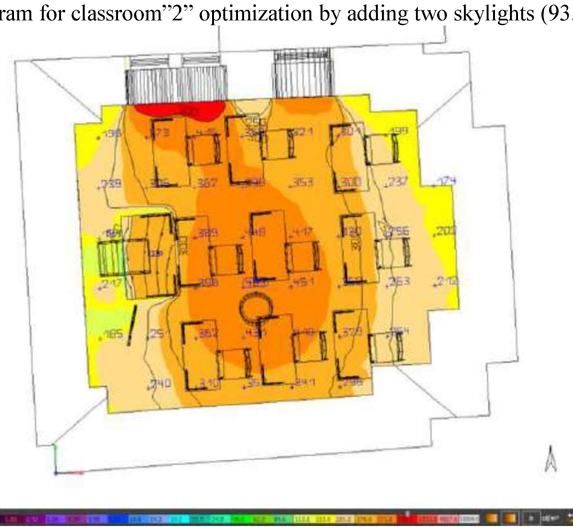

Figure 9: Contour diagram for classroom"2" optimization by adding pipe light (93.8lux to 304 lux)

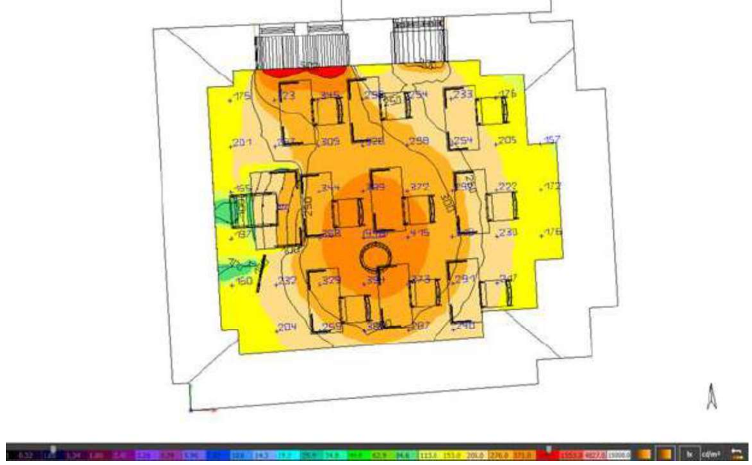

Figure 10: Contour diagram for classroom"2" optimization by adding pipe light (33.4 lux to 263 lux)

- Simulation for classroom "2" virtual model was taken over an overcast sky as a critical condition. The average of internal natural light without enhancement was 33.4 lux while readings after integrating passive light techniques (materials with light pipe) in the same condition was 263 lux. (Fig.10).

8. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the results of the daylighting analysis demonstrate that the prevailing conditions in the interior spaces of the traditional buildings of Hebron are insufficient and need to be enhanced.

The results showed a remarkable improvement in the level of natural lighting inside the interior spaces of traditional buildings equipped with passive lighting technologies especially using light pipe.

Although the attached improvements did not give the minimum required lighting for classrooms in overcasting condition (about 87%, 263 lux from 300lux), they provided sufficient lighting for daily work.

The research shows that applying passive daylight techniques in traditional buildings can make them healthier, more comfortable and truly sustainable. The entry of natural light in the environment is an essential condition for not only visual but also psychological well-being. (Santina Di Salvo, 2017)

Pipe light technology has been adopted as one of the best passive daylight techniques for enhancing the daylight in traditional buildings internal spaces for many reasons;

- In addition to passing light with an appropriate amount this light could be controllable; I e, light pipes can reduce sun glare and give daylight better uniformity (energy conservation abdus).
- It can also be linked with Active techniques to increase its effectiveness such as sun trackers.
- Many researchers found that light pipe can be linked with other passive techniques such as enhancing natural ventilation and thus take other advantages of it in addition to its main purpose
- Many researchers found that pipe light can performs other functions like providing cool natural ventilation air beside bringing daylight to the center of a large space in a house for general illumination during daytime (Surapong Chirarattananon,'et al', 2012)
- using light pipe in traditional buildings will not change the urban features of the place, in addition to it can be used to provide lighting for dark places in deep basements, and it can, unlike the skylight, be installed in more than one direction and from more than one structural element, such as ceilings, windows, walls, and inside ducts.

The use of the passive daylight techniques can provide illuminance while reducing the reliance on artificial lighting during the day, which significantly reduces the lighting energy consumption of the building.

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