International Conference and Workshop on

Sustainable Green Building Design and Construction

CAIRO, EGYPT - March 10-12, 2009

A Systematic Approach for Sustainable Design

case study:

Project of new labs center - in 6th of October city

Dr. Eng. Arch. Abdelrahman AbdelNaieem Abdellatif

Researcher in housing and Building Institute, HBRC

technical studies:

Dr. Mona Ahmed Fanny & Dr. Nabil Milad Girgis

Associate Professors in Building Physics Institue, HBRC

Code: **G011**
Paper Title: **A Systematic Approach for Sustainable Design**

Introduction:
At the beginning of 2008 HBRC (Housing and Building National Research Center) organized an internal architectural competition for the design of his new labs center in the city of "6th of October" on a 10 Fadden site. The main purpose was to accommodate all needed tests and researches supported by state of the art labs units, service facilities and infrastructure. At the same time the design must reflect the latest and highest international standard for such project.
The project presented in this paper won the first prize in this competition. The following aims and objectives were fundamental in the design process:

1. To establish the most adequate center for all building testes and researches at the national and regional level,
2. To achieve the highest standard of quality and performance compared with similar international institutions,
3. To set an example in applying design principles of sustainability and green architecture, as well as an expression of modernity and originality.

Sustainable and green building design principles and tools have been utilized to develop and guide the whole design process. A lot of time has been spent to revise, improve and redevelop the given program to insure the realization of the main project objectives. Qualitative and quantitative programs' parameters have been taken into consideration. The participation of users (researchers and technical staff) has been applied in both phases of program development, and evaluation of planning alternatives. Architectural, structural and technical aspects have been taken into account to comply with the contemporary international lab design guides and codes.

I. Architectural Design development process:

Development of the design process for this project went through three main phases:

1- revising the architectural program,
2- Preparing a checklist of the design considerations and
3- Finally developing the architectural design concept.

1. the program

The successful design depends basically on a well prepared program. This program should describe qualitatively and quantitatively the project elements as well as the internal relation among them, and should reflect the whole expected and predicted user needs and activities.

The well documented and analyzed activities as well as its necessary equipment give full description of the needed spaces. 1st Built form of spaces; for example: closed spaces (such as internal spaces like control rooms), or open spaces (such as external spaces like parking), or semi open spaces (like shaded areas). 2nd Quantity of spaces and that mean dimensions and repetition of spaces. 3rd Quality of spaces and that mean the conditions of physical environment which needed to use the space healthy, safely and comfortably. (See fig. 1)

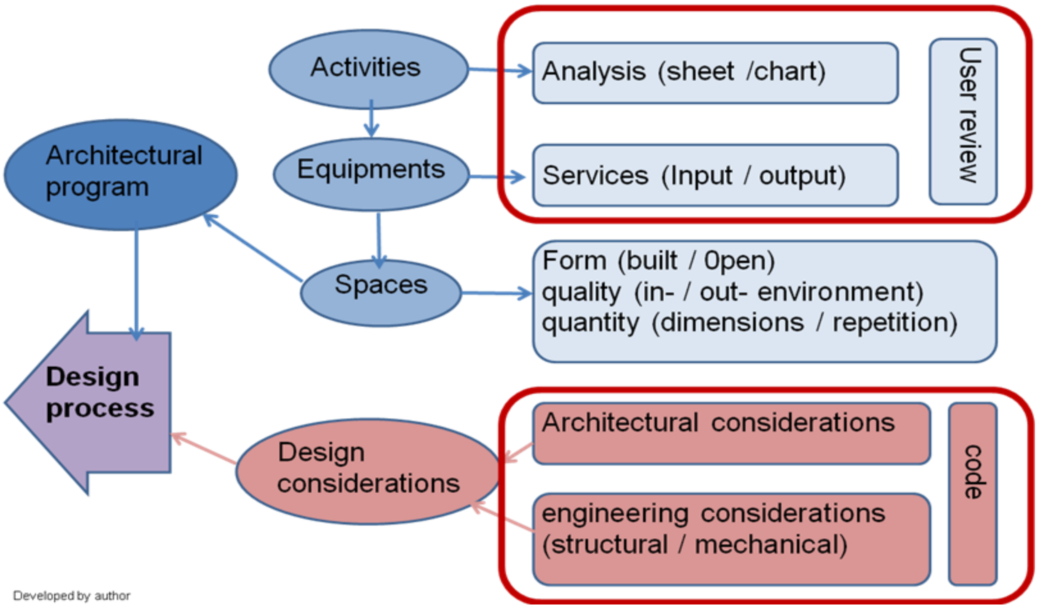
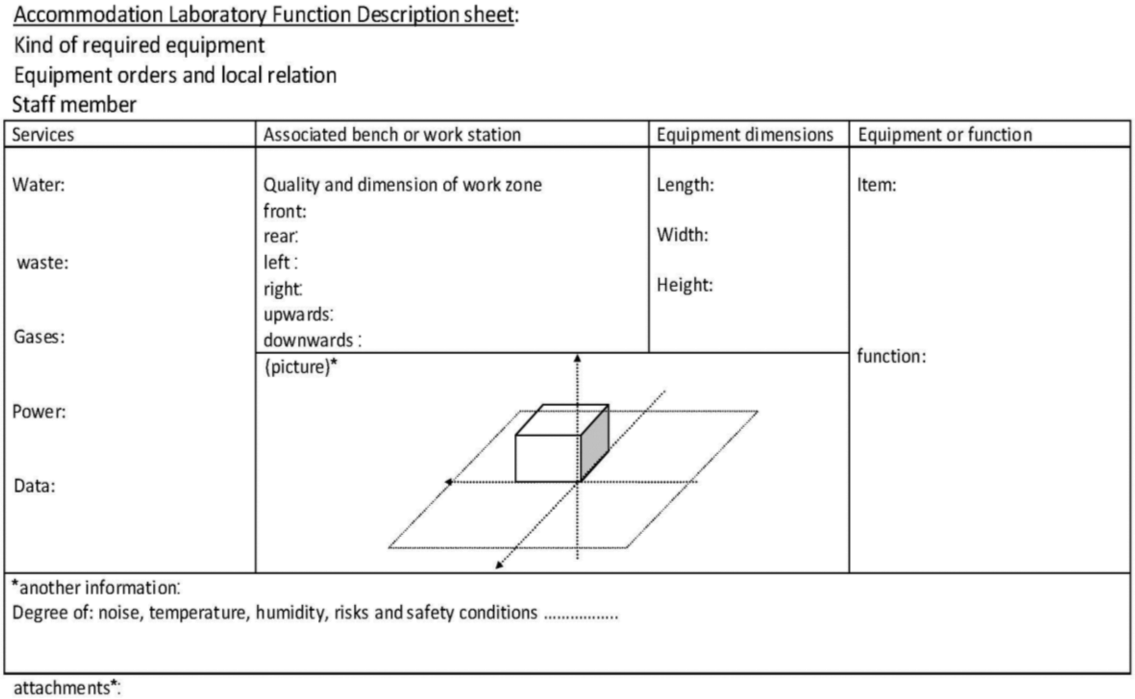


Fig. 1: development process of project

For that purpose job description sheet (fig. 2) was used, as one of data gathering tools, to define the three parameters of the required labs spaces **FQQ** (From, Quality and Quantity). This sheet also is the instruments to realize the user participation in this phase. Every sheet gives the essential information for each lab's equipment: its function, its dimensions, associated work spaces also required services and environmental conditions.
The sheets have been filled by scientific and technical staff, and were discussed and reviewed with them through the development of design process. According to the analysis output of the different activities and its related equipments, deferent sets of functional spaces have been gathered in groups. Those groups define the basic program's elements, which reflect two things: firstly - the main functional spaces and its servicing spaces, secondly - the positional relationship among the functional spaces or project's elements.
The project's elements have been arranged in main four groups:
1st group is **general administration**, which include all these elements: administration depts., security, connections unit, information center and main library.
2nd group is **conferences center**, which include the main auditorium, meetings rooms, exhibition and restaurant.
3rd group is **engineering labs**, which consist of two sub groups: energy & environmental labs as one and the other the building construction labs.
4th group is standard **labs**, which include all the physic and chemist labs.


Accommodation Laboratory Function Description sheet:
Kind of required equipment
Equipment orders and local relation
Staff member

Services	Associated bench or work station	Equipment dimensions	Equipment or function
Water: waste: Gases: Power: Data:	Quality and dimension of work zone front: rear: left : right: upwards: downwards : (picture)*	Length: Width: Height:	Item: function:

*another information:
Degree of: noise, temperature, humidity, risks and safety conditions ....

attachments*:

Fig. 2: functional description sheet[1]

lab	Nr. of sheet	attachments	sketches
Metal constructions testing	1	6	1
Structural and earthquake simulation	19	-	-
Lifts testing	7	-	-
Fire testing	3	2	-
Moisture isolations testing	1	-	1
Electrical testing	3	-	1
Acoustics testing	9	3	-
Wind tunnel	7	-	1
Nano lab	4	3	-
Pipes testing	14	-	1
Air condition lab	2	-	-
Natural light and glazing lab	14	-	-
Buildings physical performance lab	11	-	-

Table 1: output of description sheets for different labs

Figure 3 is the functional zoning diagram of the project, which shows the relationship among the main four groups, also the entire project built elements and the proposed kind of accessibility among those groups. As in diagram general administration and conferences center is presented as a strongly related one functional body and in other side all kind of labs present the other one. The different alternatives of land use

[1] Adopted from; B. Griffin, Laboratory Design Guide, 2000

planning, layout concept and architectural as well structural forms will be guided according to this diagram.

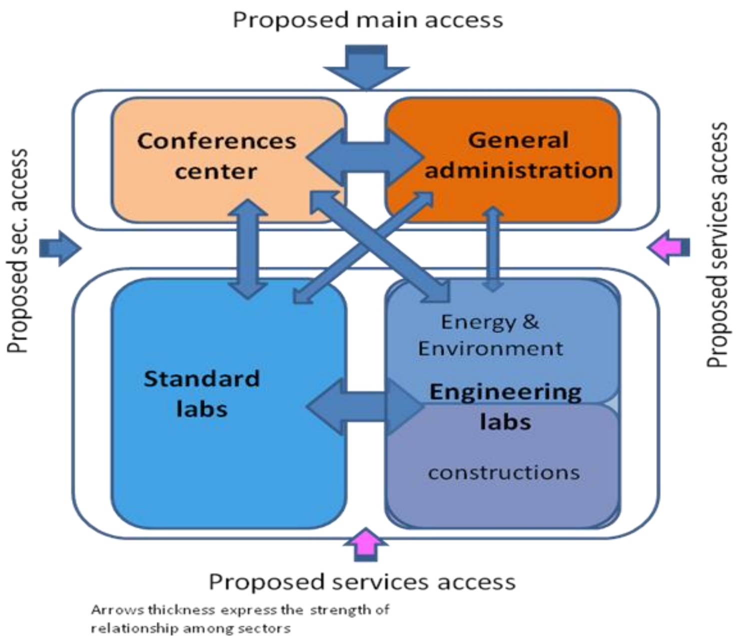


Fig. 3: functional zoning diagram

2. Design considerations

Research Laboratories are workplaces for the conduct of scientific research. These design considerations will summarize the key architectural, engineering, safety, and sustainability considerations for the design of Research Laboratories. Labs design considerations in the 21st century have been developed to create research laboratories that are responsive to current and future needs, that encourage interaction among scientists from various disciplines, that help recruit and retain qualified scientists, and that facilitates partnerships and development.[2]

A. Architectural Considerations:

Over the last years, architects, engineers, facility managers, and researchers have refined the design of typical labs and the following identifies the best solutions in designing a typical lab.

Lab Planning Module

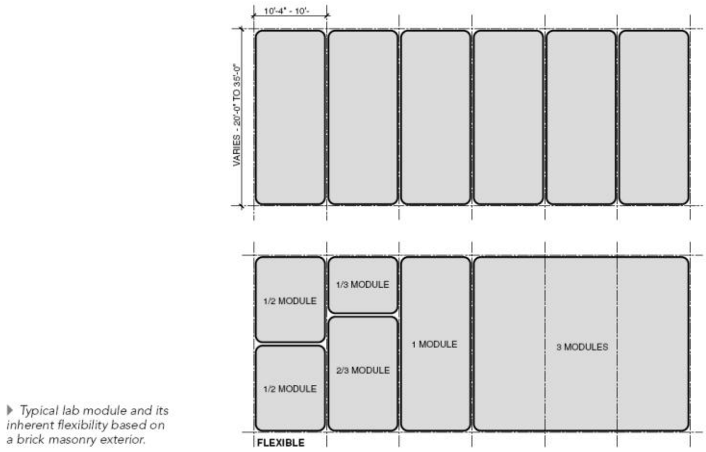
The laboratory module is the key unit in any lab facility. When designed correctly, a lab module will fully coordinate all the architectural and engineering systems. A well-designed modular plan will provide the following benefits:

- **Flexibility** - The lab module should "**encourage change**" within the building.[3] **Expansion** - The use of lab planning modules allows the building **to adapt** to needed expansions or contractions without sacrificing facility functionality.

[2] www.wbdg.org/ design/lableed

[3] For more information see WBDG Productive - Design for the Changing Workplace

A common laboratory module has a width of 3m (10 ft.) but will vary in depth from 6 to 9m (20-30 ft.). The depth is based on the size necessary for the lab and the cost-effectiveness of the structural system. The 3 m dimension is based on two rows of casework and equipment (see fig.4). Lab module is very important also to coordinate all the mechanical, electrical, and plumbing systems in the ceiling and vertical shafts for utilities.



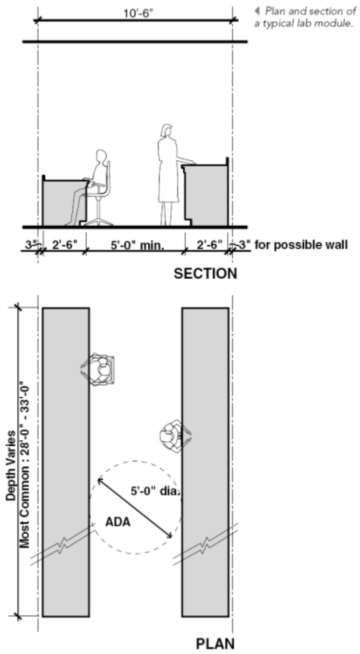


Fig. 4: lab module as s basic unit[4]

Lab Planning & Functional Zoning Concepts

The relationship of the labs, offices, and corridor will have a significant impact on the image and operations of the building.[5]

Zoning the building between lab and non-lab spaces will reduce costs. Labs require natural daylight and 100% outside air while others non-lab spaces can be designed with re-circulated air. Special instruments and equipment, such as nuclear magnetic resonance (NMR) apparatus, electron microscopes, and lasers cannot function properly in natural light. So those must be located in the interior of the building. There are many variations for adjacencies (spaces or functional zoning) with corridors, which can be organized with a single, two corridors (racetrack), or a three corridor scheme. A single corridor type has been chosen for the project because it is environmentally and economically the most suitable alternative for our local context. (See – fig. 5)

The main functional zonings for labs are defined as follow:

- **Lab Work Station Unit**: this unit is the main space or area to carry out specific tests, scientific researches or training.
- **Direct support zone**: this includes all the spaces, which have direct access to work station units such: as control or observing rooms, preparing tests specimens, dark room and rooms for sensitive electronic equipments.

---

[4] D. Watch, Perkins & Will: **Building Types Basics for Research Laboratories**, JOHN WILEY & SONS, INC, 2001.

[5] For more information see WBDG - Functional Account for Spatial Needs

- **Write-up area**: this includes all areas with no direct relation by lab unit such as researcher offices, secretary, archives, public relations … ect.
- **Basic support zone**: which includes all reception areas; meetings rooms and services rooms for receive samples, toilets, mechanical and electrical installations, waste collection, first aids ……

B. Engineering Considerations

Typically, more than 50% of the construction cost of a laboratory building is attributed to engineering systems. The close coordination of these ensures a flexible and successfully operating lab facility.[6]

Structural Systems

Once the basic lab module is determined, the structural grid should be evaluated. In most cases, the structural grid equals 2 basic lab modules, and then the structural grid would be efficient and cost-effective. Key design issues which should be considered in evaluating a structural system include:

- Framing depth and effect on floor-to-floor height
- Ability to coordinate framing with lab modules
- Ability to create penetrations for lab services in the initial design as well as over the life of the building
- Potential for vertical or horizontal expansion
- Vibration criteria
- Cost.

Mechanical Systems

The location of main vertical supply and exhaust shafts as well as horizontal ductwork is very crucial in designing a flexible lab. Key issues to consider include: efficiency, flexibility, modular design, initial costs, long-term operational costs, building height and massing, and design image.

Electrical Systems

Three types of power are generally used for most laboratory projects:

a- Normal power circuits are connected to the utility supply only, without any backup system. Loads are including some HVAC equipment, general lighting, and most lab equipment.

b- Emergency power is created with generators that will back up equipment such as refrigerators, freezers, fume hoods, emergency lighting, exhaust fans, and environmental rooms.

c- An uninterruptible power supply (UPS) is used for data recording, certain computers and microprocessor-controlled equipment. The UPS can be either a central unit or a portable system.[7]

The following should be considered:

- Load estimation
- Site distribution
- Power quality
- Management of electrical cable trays/panel boxes
- Lighting design

---

[6] For more information see WBDG - Functional Ensure Appropriate Product/Systems Integration

[7] For more information see WBDG - Productive Assure Reliable Systems

- User expectations
- Illumination levels
- Uniformity
- Lighting distribution—indirect, direct, combination
- Luminaire location and orientation—lighting parallel to casework and lighting perpendicular to casework

- Telephone and data systems

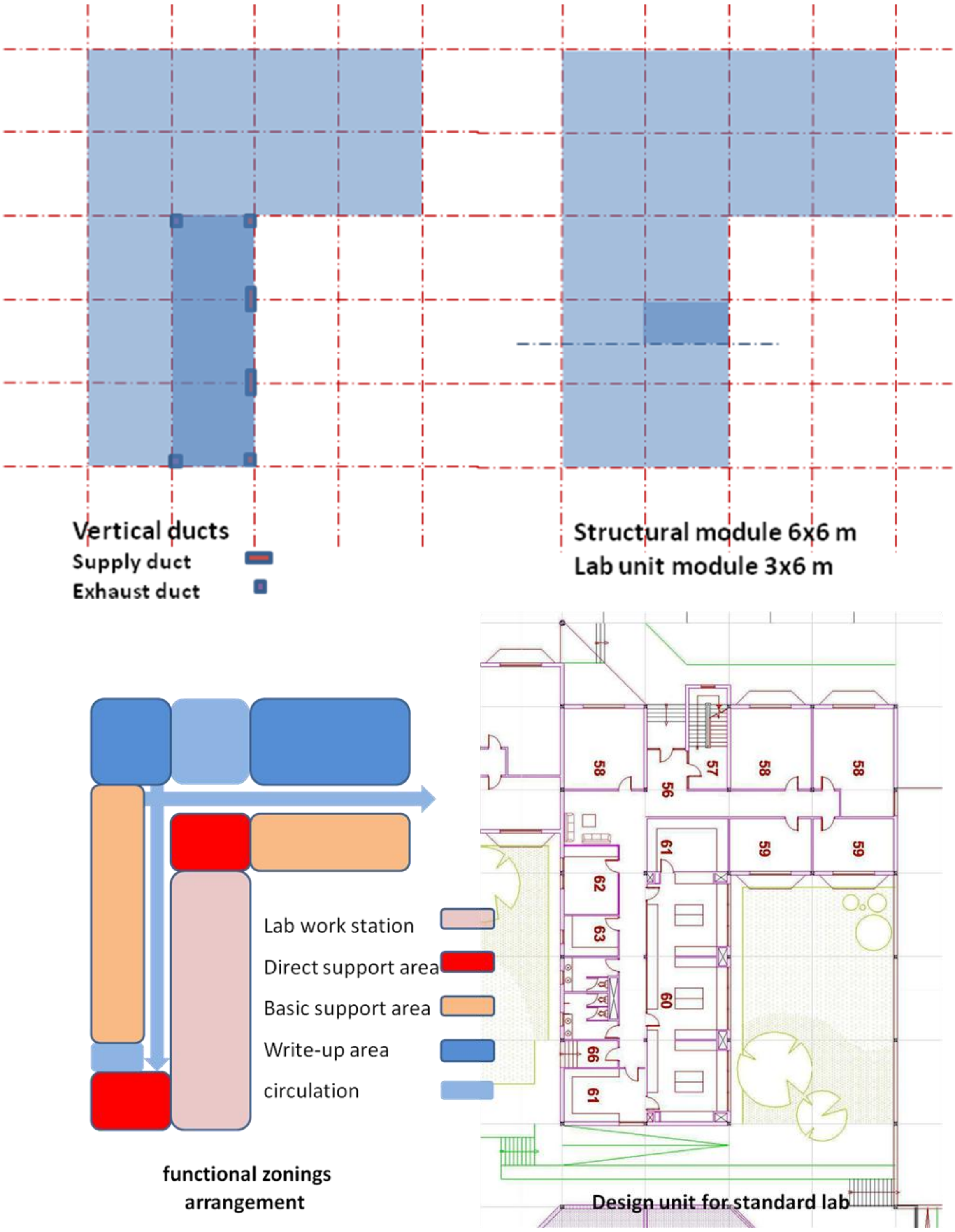


Fig. 4: Design process for standard lab

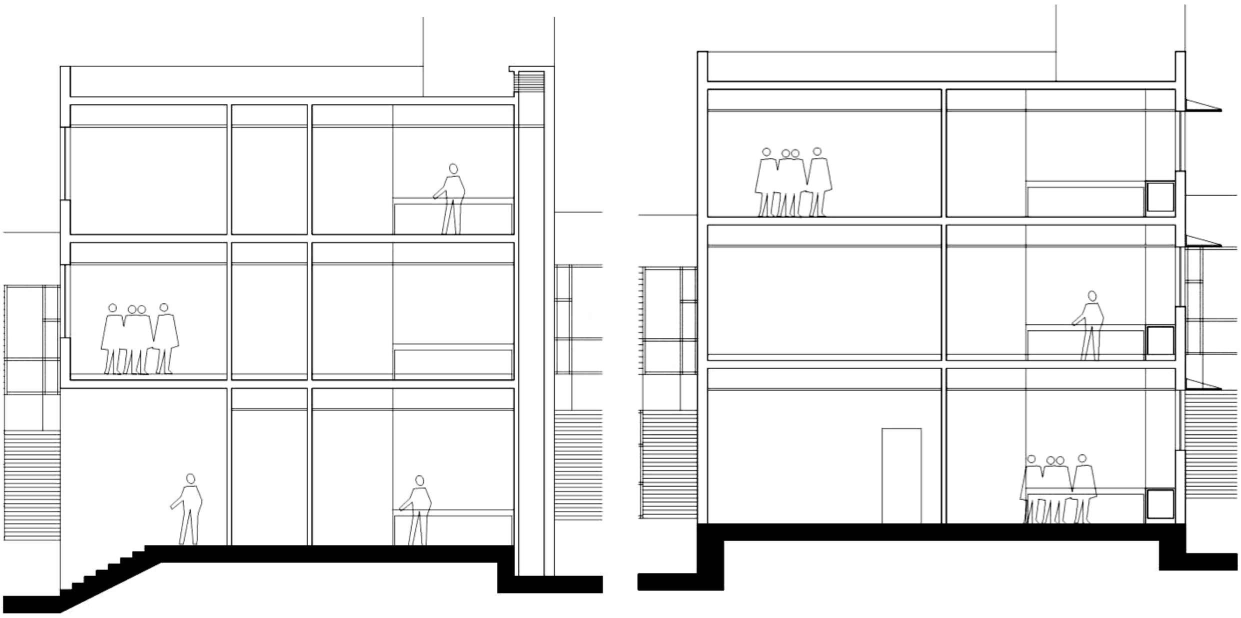


Fig. 5: standard lab cross sections

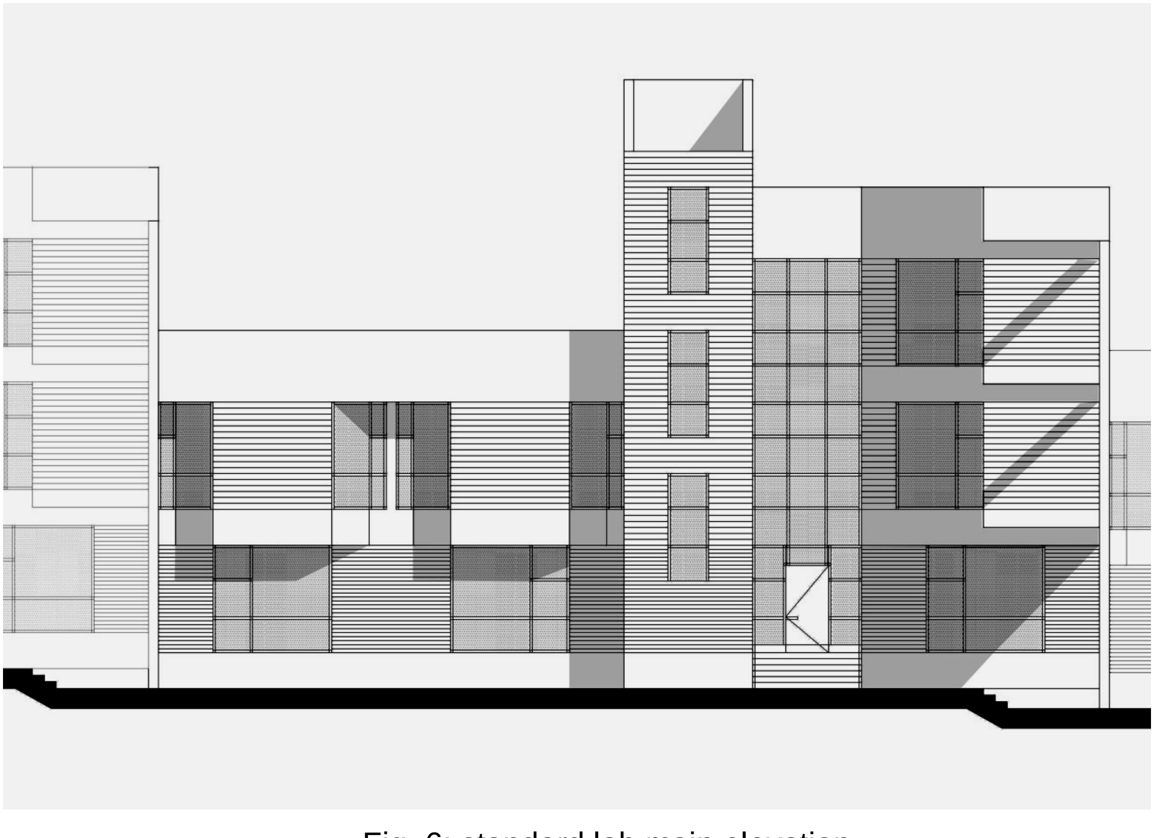


Fig. 6: standard lab main elevation

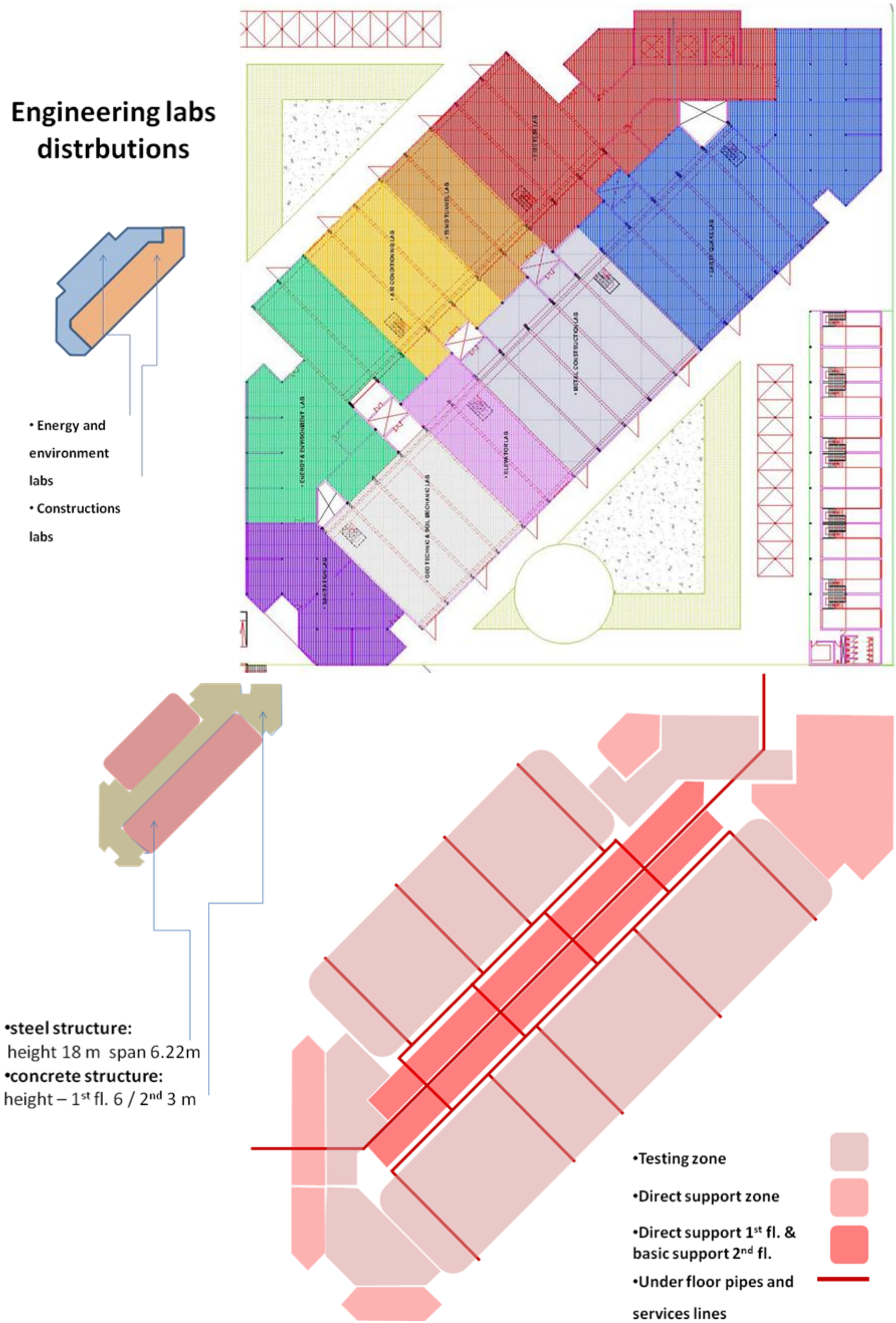


Fig. 7: Engineering labs design

Piping Systems

There are several key design goals to strive for in designing laboratory piping systems:

- Provide a flexible design that allows for easy renovation and modifications.
- Provide appropriate plumbing systems for each laboratory based on the lab programming.
- Provide systems that minimize energy usage.
- Provide equipment arrangements that minimize downtime in the event of a failure.
- Locate shutoff valves where they are accessible and easily understood.
- Accomplish all of the preceding goals within the construction budget.

C. Sustainability Considerations:[8]

The typical laboratory uses far more energy and water per square foot than the typical office building due to intensive ventilation requirements and other health and safety concerns. Therefore, designers should strive to create sustainable, high performance, and low-energy laboratories that will:

- Minimize overall environmental impacts
- Protect occupant safety
- Optimize whole building efficiency on a life-cycle basis

D. Relevant Codes and Standards

There are many international agencies and organizations have developed codes and standards affecting the design of research laboratories. These codes and standards are presenting minimum requirements. Architects, engineers, and consultants should consider exceeding the applicable requirements whenever possible.

3. Architectural design concept

Architectural design concept has been guided by mentioned above design consideration and applied the principle of sustainability and green building.
Three design alternatives has deeply developed and evaluated according to the following checklist of design criteria:[9]

- **The Site** (advantages and constrain)
- **The Changing Brief** (needs changing & future development expectations)
- **Generic not Specific** (flexibility & adaptation)
- **OH & S** (Occupational health and safety)
- **Energy Efficient Design** (environmental control & renewable energy)
- **Decentralized mechanical plant** (appliances maintain and control)
- **Professional Interaction** (formal and informal interaction of staff)
- **Separate write-up and lab spaces for OH&S** (zonings arrangement)
- **Lab furniture** (mobility, flexibility, adaptability)

[8] For more specific guidance, see WBDG Sustainable Laboratory Design; EPA and DOE's Laboratories for the 21st Century (Labs21), a voluntary program dedicated to improving the environmental performance of U.S. laboratories; WBDG Sustainable Branch and Balancing Security/Safety and Sustainability Objectives. See also - the WBDG Resource Page Using LEED on Lab Projects

[9] B. Griffin, LABORATORY DESIGN GUIDE, 2000, p. xiv - xvi

- **Physical containment** (air quality, risks, energy control)
- **Illumination** (mix use of natural and low voltage artificial light)
- **Noise** (internal and external noise control)

Intensive disunions have been carried out with representatives from different research institutions in many meeting according to above criteria to choose the best alternative.

The selected alternative has been developed in complete set of architectural drawings. At the same time two technical environmental studies and tests carried out by cooperated two staff members of environmental institute in HBNRC. The first study was carried to investigate the level of thermal comfort, calculate the intensity of natural day lighting, evaluate the required electrical lighting and utilize photovoltaic cells to produce the needed power for electrical lighting in public spaces. Second study was to simulate natural air dynamics behaviors by experimenting smoke flow around different project's models in wind tunnel, and to investigate solar radiation and shading possibilities for different building orientations.

A- Project descriptions:

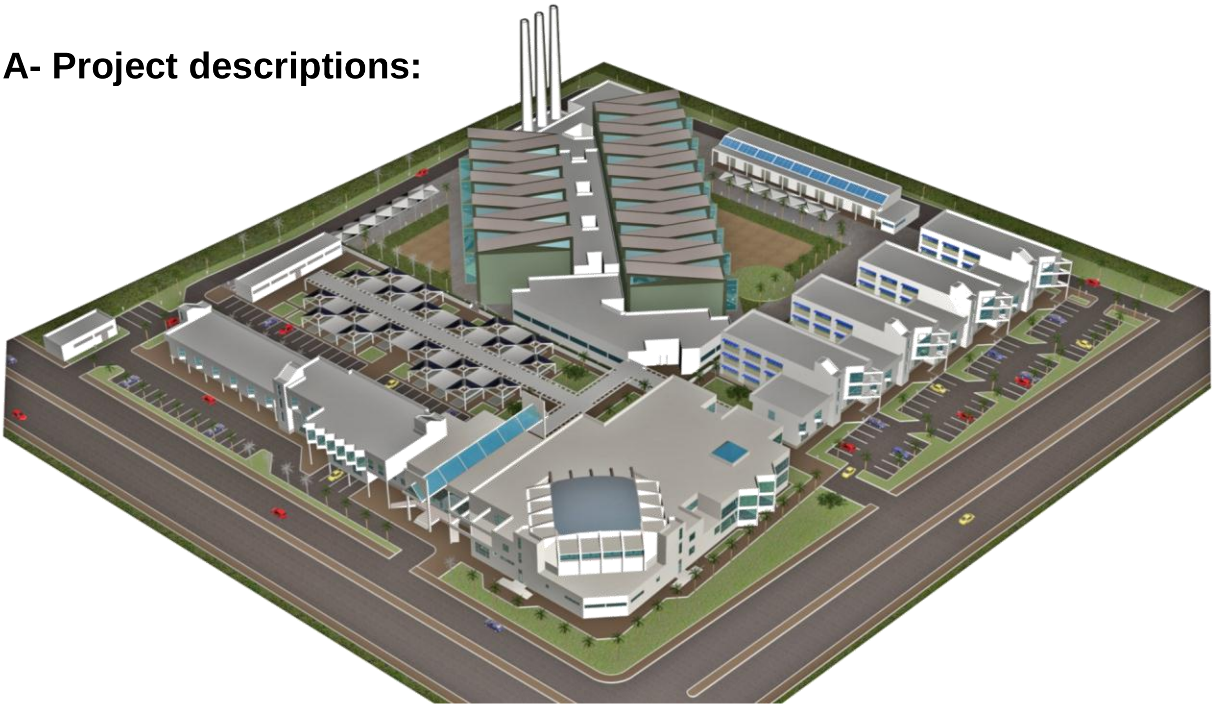


Fig. 8: general view

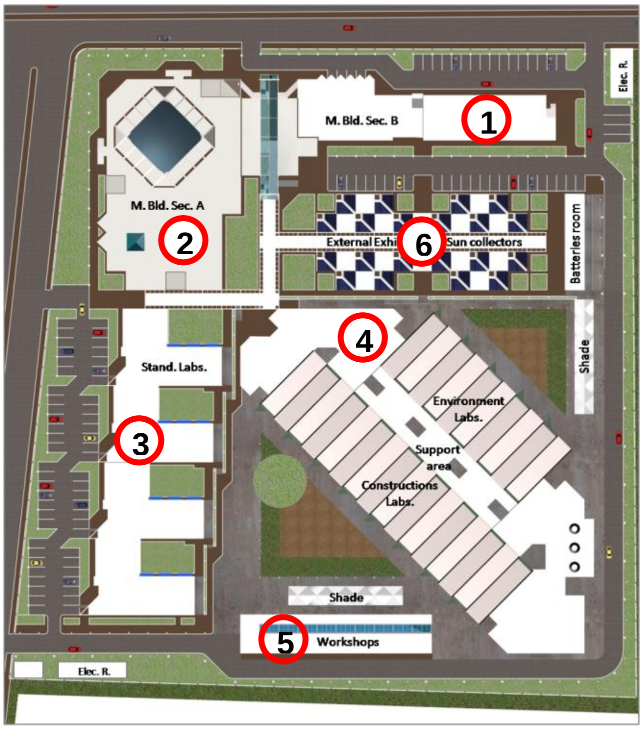
The built elements:

As is shown in fig. 8 & 9 the project consists of a complex of buildings as following: building (1), administration building, includes all administration departments, main storing, security, connections unit, information center and main library. Building (2), conferences center, includes the main auditorium, meetings rooms, exhibition and restaurant. The main entrance of project presents the connection between the two buildings. Building (3) consists of two big halls: the first includes all energy & environmental labs and the second all construction labs. The two halls are connected by low rise building contain all supporting facilities. Building (4), standard labs, consists of attached four buildings units, which include all the physic and chemist labs. Every unit has maximum three floors, each for specific lab. Building (5) contains ten different workshops with rest units for workers to serve mainly engineering's labs.

Building (6) is shaded area for external exhibition. The shade form is designed to contain the photovoltaic units. There are some other built elements like: mechanicals rooms, which should be accurately designed according to actual needs, and some shading elements for pedestrian passages or specific rest areas.

Fig. 9: site plan

1- administration building
2- conference center
3- standard labs
4- engineering labs
5- workshops
6- external exhibition shaded with photovoltaic units



Site Forming:

The normal observation of the site gives impression of flat land, but the topographical map shows a very slight slope (approx. 1%), which give a level variation about 2 m between the heights topography line in the north east side of site to the lowest line in the south east side site. Therefore the site has been divided in two big platforms, one with heights level, which above located the main building (administration & conferences center) and external exhibition, the other platform at the lowest level, where the engineering labs and workshops were located. Between these two levels, a series of small platform at the north east side of site, which formed as steps with 0.5 m of level variations, where the four units of standard labs located. (See – fig. 10)

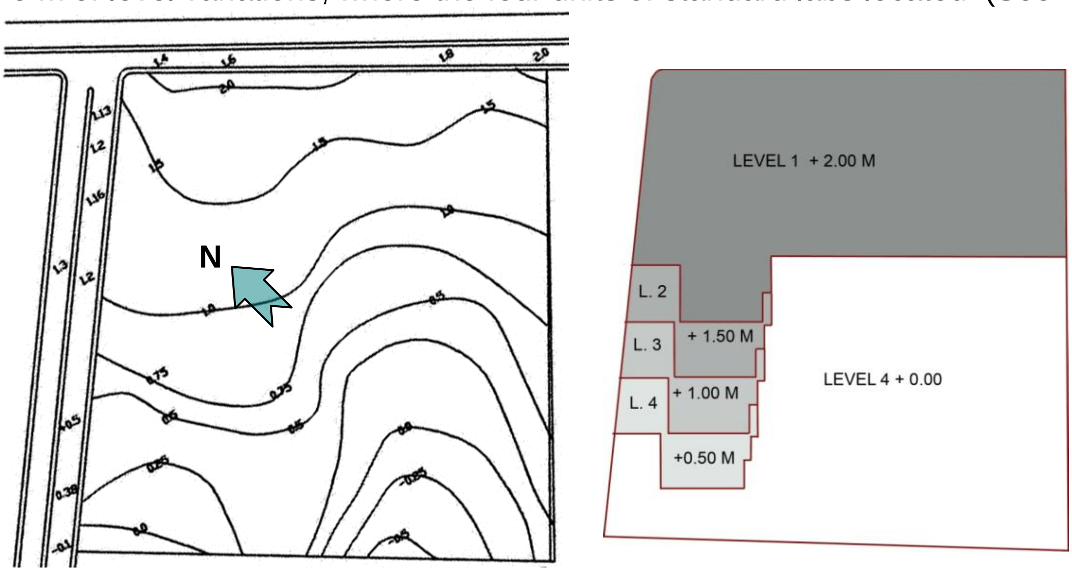


Fig. 10: site formation according to land topography

B- Accessibility, services canal, future expansions:

Three planning aspects had the priorities to develop the arrangement of built elements on the site of project, and to evaluate the different planning alternatives.
1st **Accessibility** – in the design process was the realization of best performance through the distribution net of different connections, horizontal and vertical movement elements (like: different entrances, pedestrian passages, traffic ways and different stairs types) to granite the ease of movement in project and maximum safety for the user. (See fig. 11)
2nd **Services canal** – for ease maintenance, and reducing costs for future renovation a collective protective service canal with removable covers on the main axis was planned (fig.12) to contain all the power and installation lines (pipes, cables, inspection rooms)
3rd future **expansion** – the possibility to expand the built area vertically or horizontally was planned for the most predict changeable built spaces like: administration, support areas for standard and engineering labs. (See fig. 13)

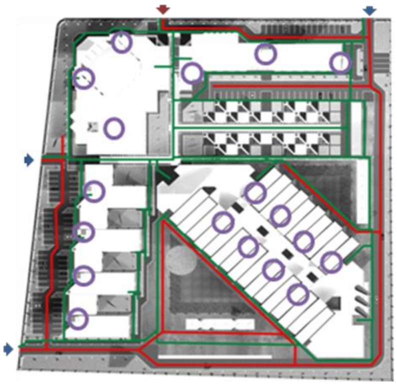


Fig. 11: horizontal and vertical movement nets

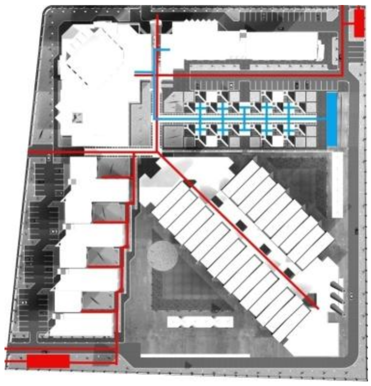


Fig. 12: service canal

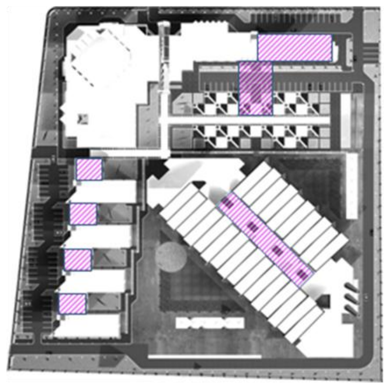


Fig. 13: future expansions

C- Environmental control:

According to green building principle and LEED (leadership in energy and environmental design) the environmental control was the main criteria in developing and forming built elements and architectural details. And two technical studies were carried out calculate the energy efficiency in design.

Day lighting and opening design:

Natural lighting is one of the important issues for saving energy in sustainable design. As well known, best orientation of the building is towards north to avoid glare and unequal distribution of lighting intensity through day hour. The opening in the project has been design to enjoy the best performance of natural lighting, for example most of offices spaces and write up area have north east and north west orientation. The opening is design to be 40% of external walls, and recessed to be shaded in work hour. In the case of south east and south west orientation, light shelves fixtures have been installed in front of windows to avoid direct sun rays and to enjoy well distributed day lighting in inner spaces. (See fig. 14)

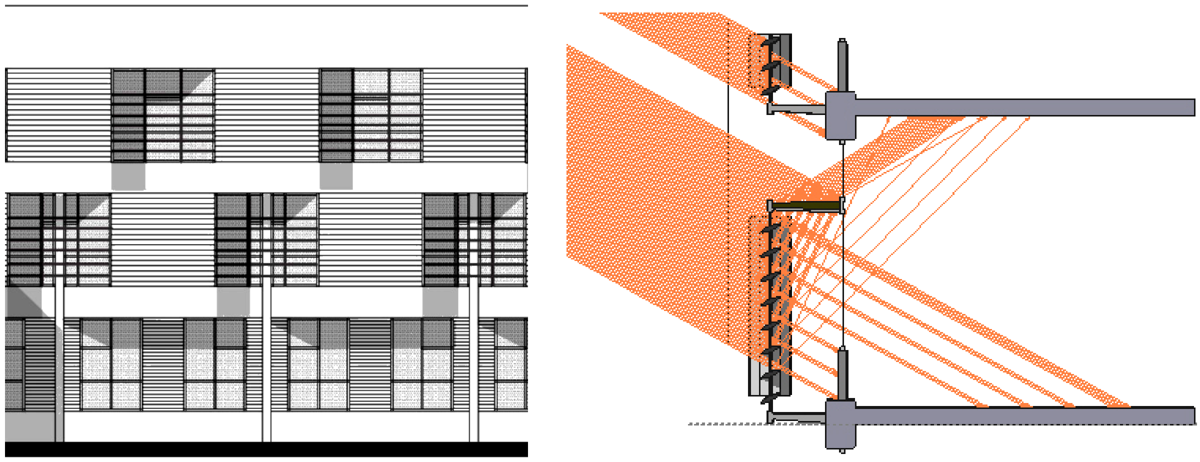


Fig. 14: utilizing light shelf fixture in front of opening

Natural ventilation:

The different means to move fresh air through spaces are important issues in the passive environmental control and sustainable design. The main reason for that is to keep the best air quality in those spaces and to keep them cool or warm according to thermal comfort. Lovers in glass walls and high openings in conference hall or in sky light in the main entrance lobby were designed for that purpose. (See fig. 15) and (see fig. 16)

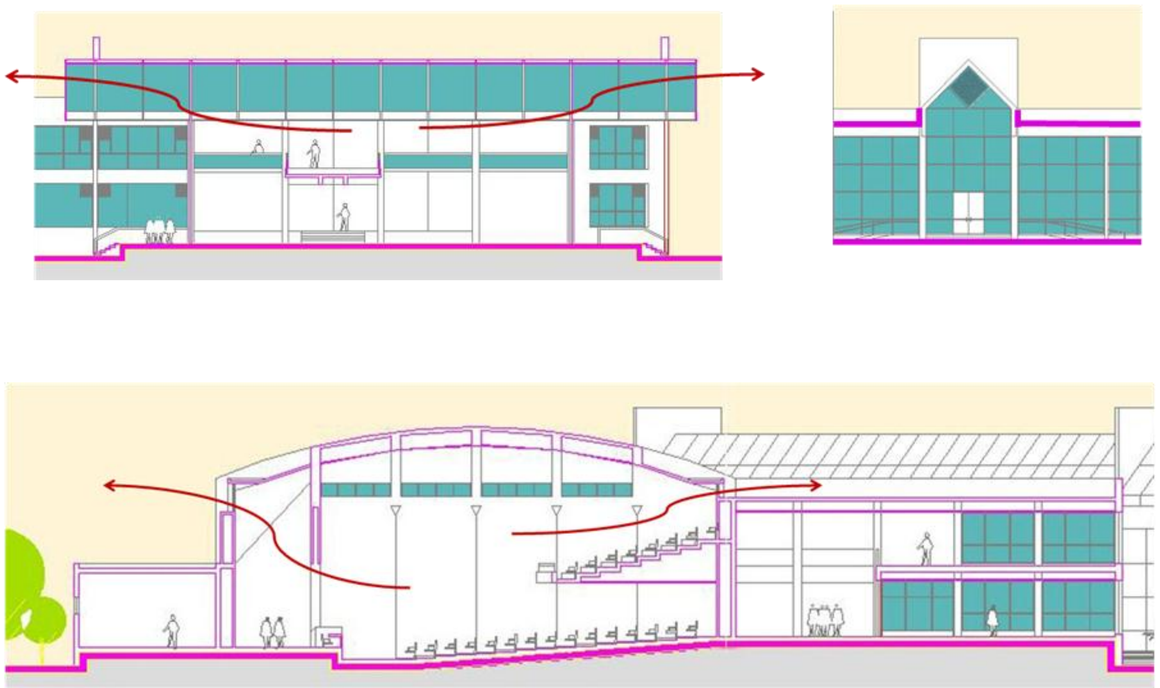


Fig. 15: suction of exhausted air from main the main lobby and conformance hall

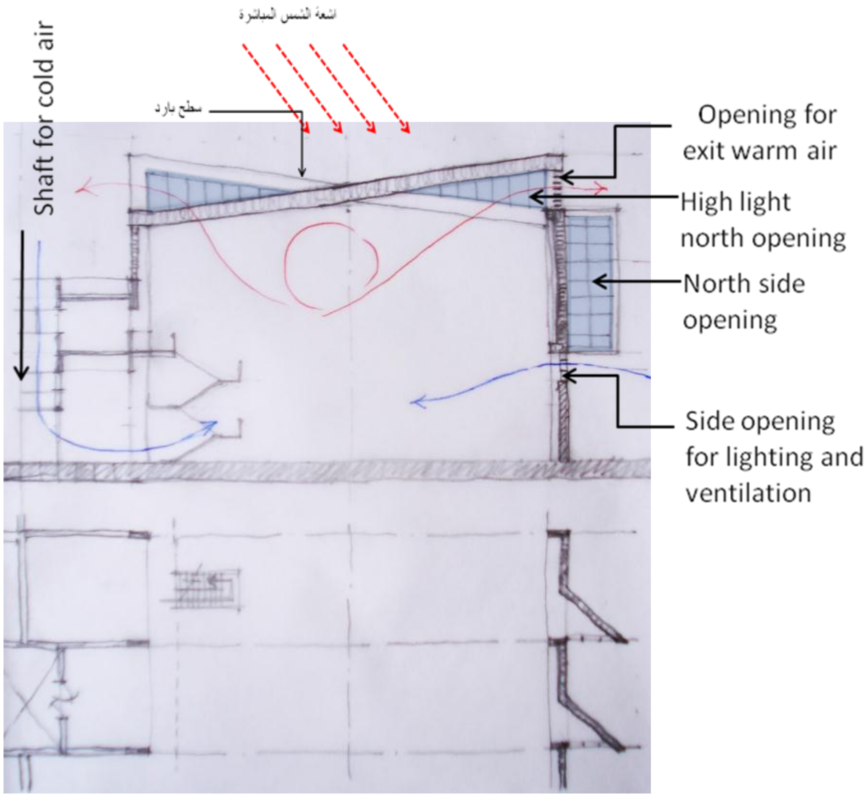


Fig. 16: sketch for section through engineering labs hall to present the principle of natural lighting and ventilation

D- Utilizing Renewable Energy:

In sustainable design utilizing renewable energy resources is presented as main subject. To realize that in our project, photovoltaic cells have been installed to produce enough electrical power for the lighting of public spaces, like main entrance lobby, main corridors and external passages in the project. Those spaces will be automatically lighted when the natural lighting level is low. For functional and esthetical reasons photovoltaic cells was used to design the shade of external exhibition. (See fig. 17)

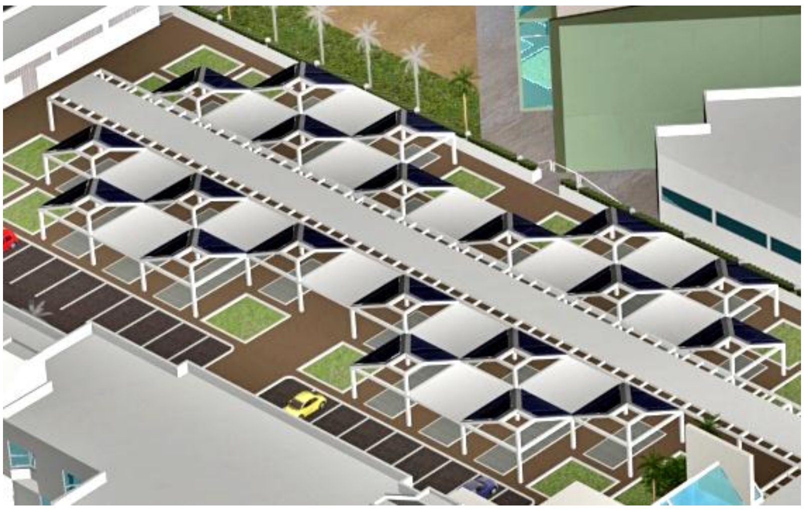


Fig. 17: photovoltaic units as a part of external exhibition shade

II. Technical Studies:

a- The Environmental Study

The study were taken into consideration the required thermal resistance for walls and roofs that is included in the energy codes (1) , which is 1.32 $m^{2o}C/W$ for south east and southwest and 1.18 $m^{2o}C/W$ for northeast and northwest and 2.3m2oC/w. We consider the assumption of using common brick of thermal resistance 0.28$m^{2o}C/W$, and according to that, the calculation of the suitable thickness of insulation is illustrated that thickness of 6cm of expanded polystyrene is suitable for SW&SE, and thickness of 3 cm is suitable for NW, NE orientation, and thickness of 15 cm is suitable for common roof construction. Relating to these data, the overall total thermal transmission for the envelopes OTTV are calculated for the enclosure that contained the largest glass area 47% which is given 63.5 W/m^2 for walls ;while it is concluded 70W/m^2 for office building(2), and given 12.8W/m^2 for exposed roofs; while it is concluded 15 W/m^2 in the code(3). So, the reached OTTV is perfect for the Research Center Laboratory Buildings in 6 October City. We could also decrease these values to more appropriate values by another choosing of building materials and insulation thickness which couldn't affect the overall building construction cost.

The study has investigated the level of thermal comfort in the suggested Center laboratory building spaces and calculated the thermal stress index (HSI) in the working places (4) with assumption of person energy emission through working is 112 W i.e 1.7met, the inside water vapour pressure is half of the outside and the change of the inside air velocity is 0.1 m/s: 1m/s due to the availability of the external wind speed in this region. The results are shown that the maximum HSI value is 57 for the maximum investigated indoor air temperature in summer 38^oC and at the least inside air velocity of 0.1m/s. This HSI value is a medium value which referring to the person could working under these conditions expect the elders, and when the air velocity be 0.3 : 1 m/s the HSI be 30 with the highest calculated indoor temperature and this value of HSI is very suitable for working in the most conditions. For lower indoor air temperature and higher indoor air velocity (32^oC, 1m/s) the HSI be 1 and this is means there is no thermal stress at all and this is the best for working. These results are shown in Fig. (1).

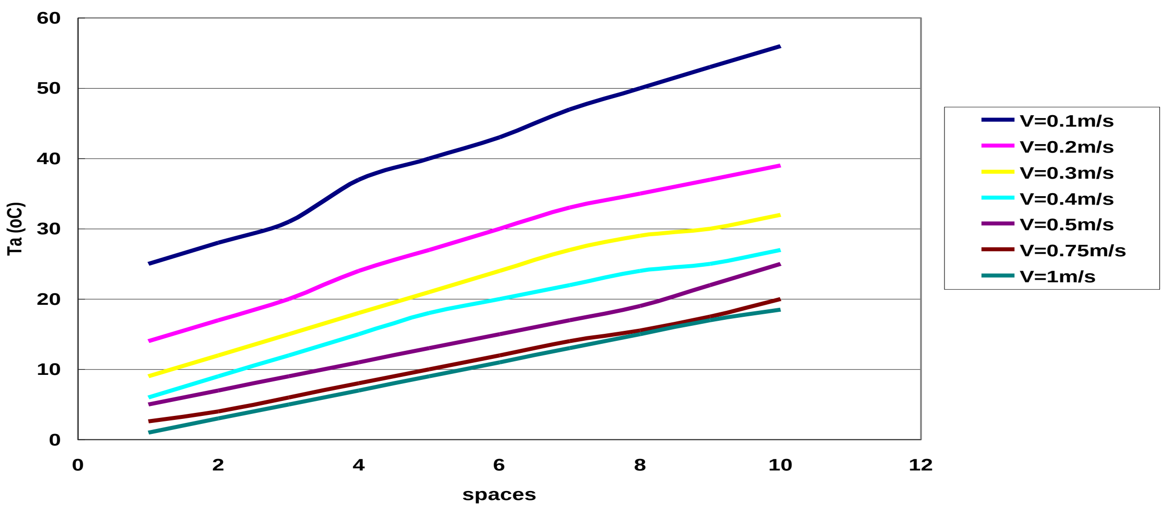


Fig (1):The variation of the Heat Stress index with Indoor air temperature and with indoor air velocity.

The study is carried out the calculation of the intensity of natural day lighting at different spaces of the buildings by the daylight factor method (5) for the mid and for the end distance of the spaces and by considering that the required level of illumination is 750 lux for office and laboratory work, and the glass visible light transmission (VLT) is 0.6 and 0.8 and there is overhangs or louvers that shed the window i.e the diffuse solar radiation is only considered for calculation the indoor illumination. A sample of results is given in Fig. (2) for two different spaces in the standard laboratories building of in winter, which shown that the level of considered illumination is achieved in the mid spaces and reaches to the half level at the end .If we consider the needed level of illumination is 500 lux, the natural day lighting could cover also the end of the spaces without need to the electrical lighting.

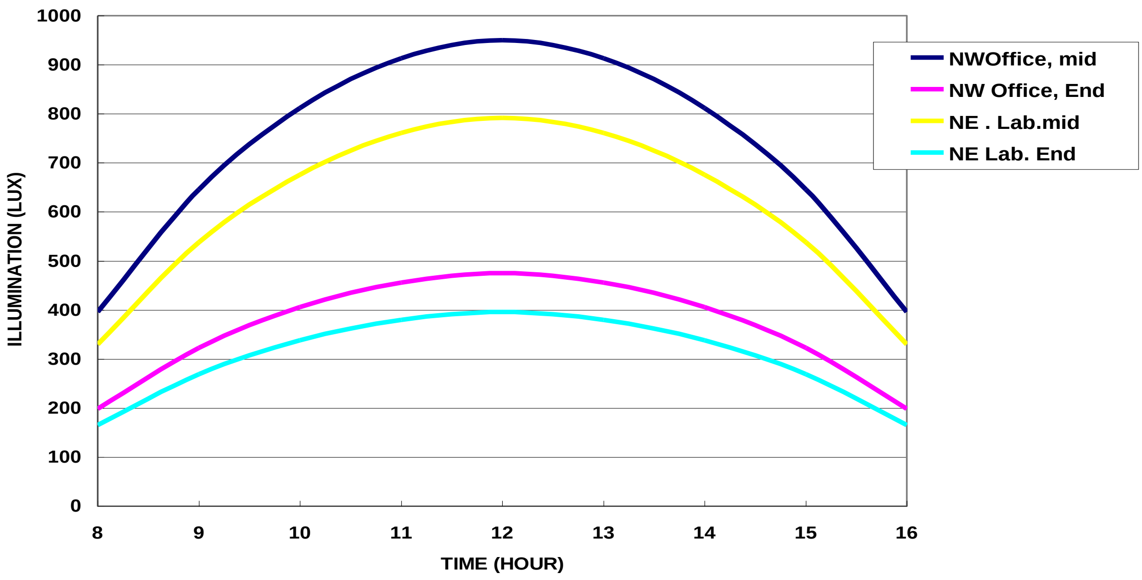


Fig.(2): The variation of daylighting illumination ot the middle and at the end of two different spaces in laboratory building in winter.

The evaluation of the required electrical lighting which could cover the need at some times of all spaces at Main buildings A, B and at standard laboratory buildings are given in summer and winter conditions and compared with a complete electrical coverage; if the design or window ratio are made without its suggested specification and couldn't achieve a mostly sufficient natural day lighting. The evaluation illustrated that the required electrical lighting power that needed; in the condition of sufficient and insufficient available natural day lighting is:

	Standard Labs	Main Building A	Main Building B	
Total Elec.light	900	238	420	KW. Hour /day
Partial Elec. light	100	41	72	KW. Hour/day

It is shown from the above values that the sufficient using of day lighting could reduce the power consumption of lighting by about 85% of its amounts without using enough days lighting in summer and about 63% in winter.

A comparison electrical lighting power (6)that needed with different changes of VLT, Glass, height above sitting place, glass area and room depth are given for NW offices and NE laboratories for daily working hours in summer, the results are shown in Fig.(3) with the evaluation values of the glass load. The study calculations are shown that the required electric power for electrical lighting for all total buildings at the maximum hours needed at 8A.M or 16 P.M. is 31 KW in summer and 103 in winter; while the most spaces of buildings didn't need to electrical lighting at all through 11:14 hours in summer and need to 30% to 50% through these hours; from that needed at early hours in winter.

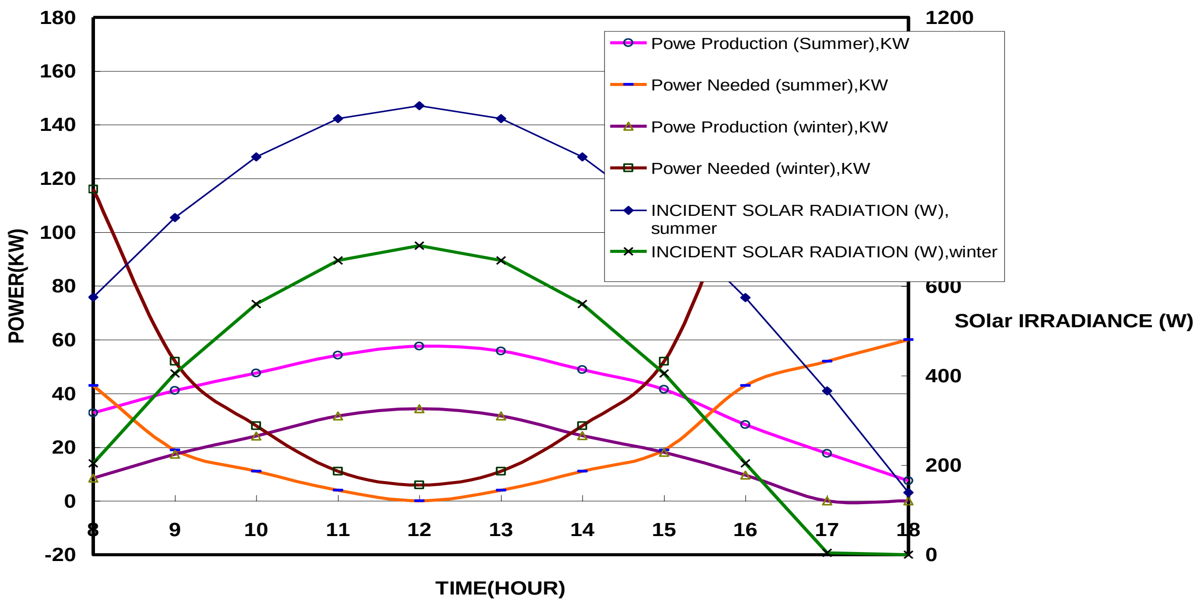


Fig.(4): The variation of Power Production by Photovoltaic solar cells and the needed Buildings lighting power with the incident solar Irriance in summer and winter for Center laboratory buildings in 6 October City, Cairo.

The study also has taken in consideration the using of solar energy as photovoltaic cells (7) to give part of the power needed to the electrical lighting. The allowed area is 8 with 144m^2 for each, 4 of them are inclined by 20^o whose total area is 576m^2. So by using solar cells with 12% efficiency – The efficiency reaches to 14% for some types of photovoltaic cells nowadays- and as the average of incident solar radiation in Cairo, Egypt is about 1000W/m^2 at 11-13 hours, then the allowed production power is 117W/m^2; then the total power production will be 57.6KW per hour then it is 230KW.Hour for hour operation from 11:13. So, as the total daily needed electric lighting power is 182 KW per hour in summer (for 8:11and at 16 h and by adding the needed lighting for stairs and tunnels), This the photo voltaic production could cover it exactly with considering storage and connections loses by 33% of the power production. In winter the total need is 478KW per hour , and the photovoltaic cells production is decreased due to the decrease of incident solar irradiance 110KW.hour (after losses) which could cover the first or 1st hour only or by neglecting them it could cover 1.3 hour of that hours started after 9 a.m. Fig. (4) illustrated the variation of photovoltaic cells power production & power needed versus incident solar radiation through summer and winter months.

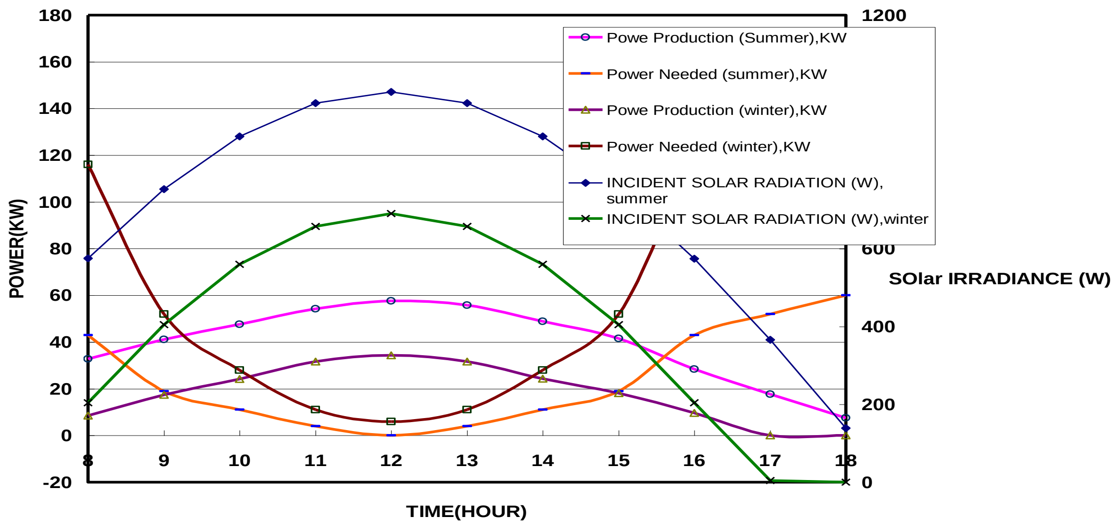


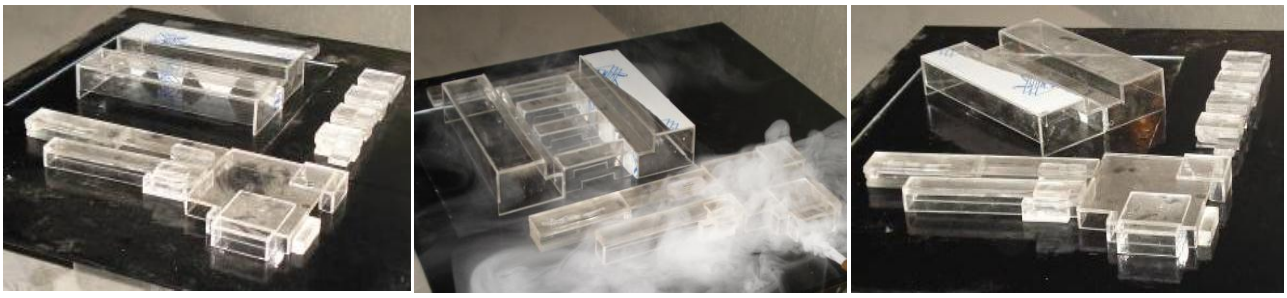
Fig.(4): The variation of Power Production by Photovoltaic solar cells and the needed Buildings lighting power with the incident solar Irriance in summer and winter for Center laboratory buildings in 6 October City, Cairo.

b. Experimental and theoretical investigation of air flow around buildings model of Housing and Building National Research Center (HBRC) at six of October city.

Towards the green building strategists the climatic factors such as Solar radiation intensity and wind speed and direction affect the thermal performance of buildings and also affect the indoor environment. The aim of this work is to study the air flow around buildings to maximize the air flow between the buildings units which yields to walls and roofs cooling and also maximize the air flow inside buildings units and in accordance achieve in reduction in indoor air temperature. The study includes also the best building units' orientation and window constructions to achieve minimum solar radiation in summer seasons and maximize the solar radiation in winter. This work includes experimental study on building model which was fabricated in wind tunnel lab- HBRC Egypt, as shown in fig. 1 a-b-c. This model was studied in a wind tunnel test facility using a smoke generator to investigate the air flow around and between the building units as white stream of smoke. The air movement was photographed using a high sensitive camera and a video camera. The paper includes also theoretical study using a software computer program (Ecotect) to investigate the solar shading for different window construction and orientation.

- **Experimental Results:**

The HBRC model was studied experimentally using three different building models arrangements, first one the central laboratory units are parallel with the main building unit, fig 1-a, second the laboratories are perpendicular with the main building unit, fig. 1-b and third, the laboratories are tilted with nearly 45^{o} with the main façade, fig. 1-c. the air flow direction was changed with the main façade of the model.



(a) first arrangement (b) second arrangement (c) third arrangement

Fig. (1): A photos of HBRC model with three different laboratories locations

Figure 2 shows the smoked air flow between the building model units for the first unit's arrangement, it is noticed that for different air flow directions with the main façade the air spread through the main building and researcher buildings but diminish at the rare (back) units of the HBRC model. That is due to the increase of turbulence flow between the front units of the building.

Fig. (2): Pictures of air flow through the model units, (Case No. 1).

Figure 3 shows the smoked air flow patterns between the building model units for the second units' arrangement and with different air flow directions. It is noticed that the different air flow directions with the main façade the air spread through the facing units such as the main building and researcher buildings but diminish at the rare (back) units of the HBRC model due to increasing of turbulence flow.

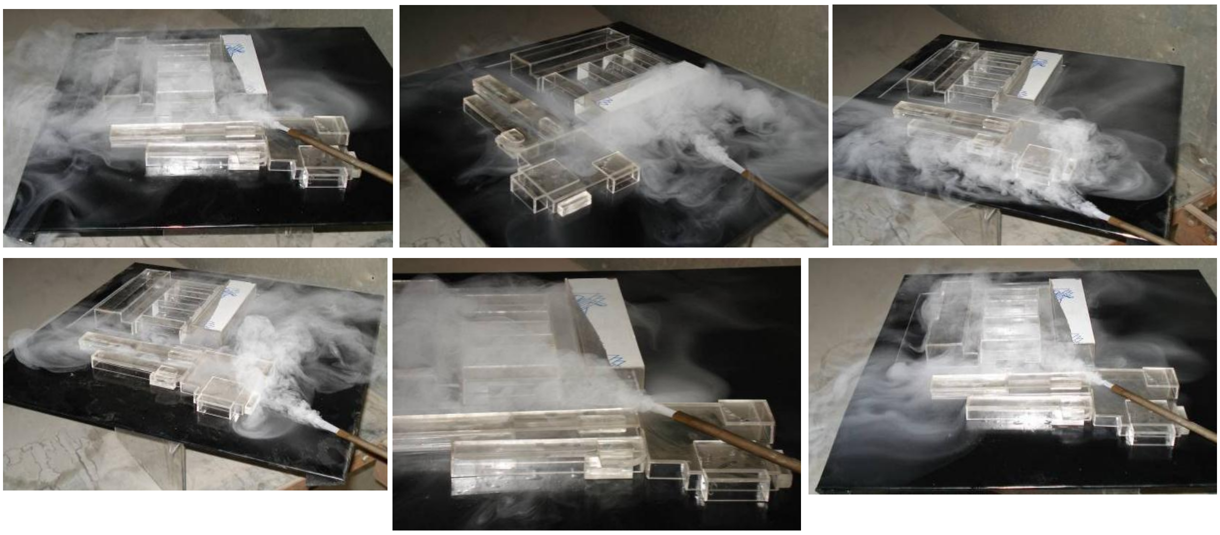


Fig. (3): Pictures of air flow through the model units, (Case No. 2).

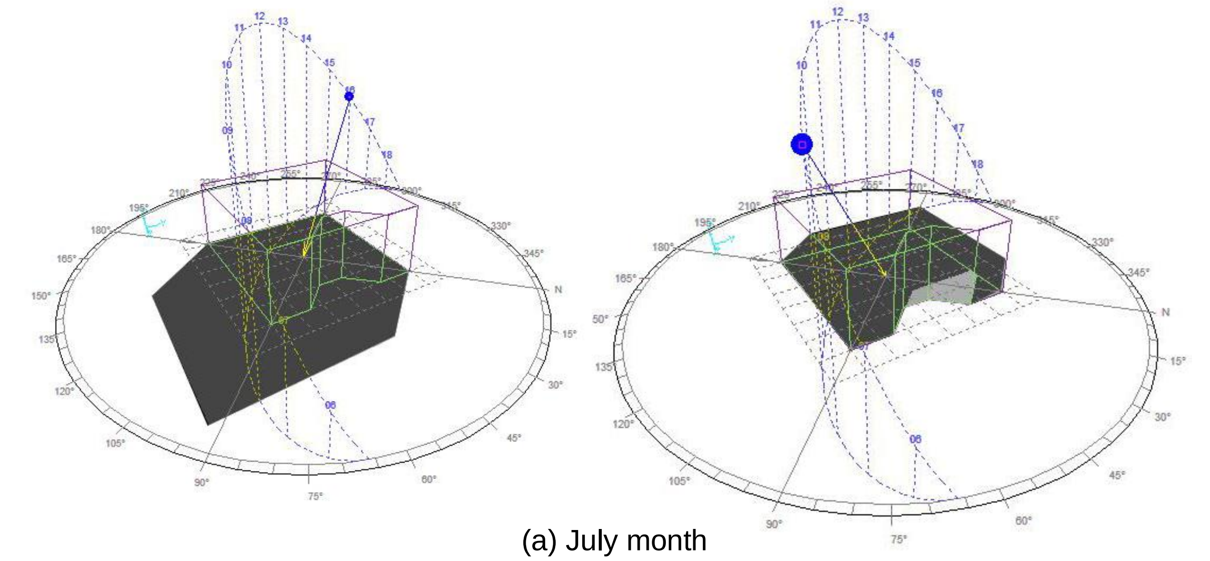
Figure 4 Show some pictures of the smoked air flow through the HBRC model units for the third arrangements. From the pictures it is clear that the air flow spread through the model units with uniform flow (i.e. low turbulence) for a long distances than the other two cases so the air floe spread to the back units causing air circulation at the rear units. This model arrangement attains more air flow and circulation between the model units which cause of reduction in walls temperature and the application of natural ventilation inside the model units may take important place.

Fig. (4): Pictures of air flow through the model units, (Case No. 3).

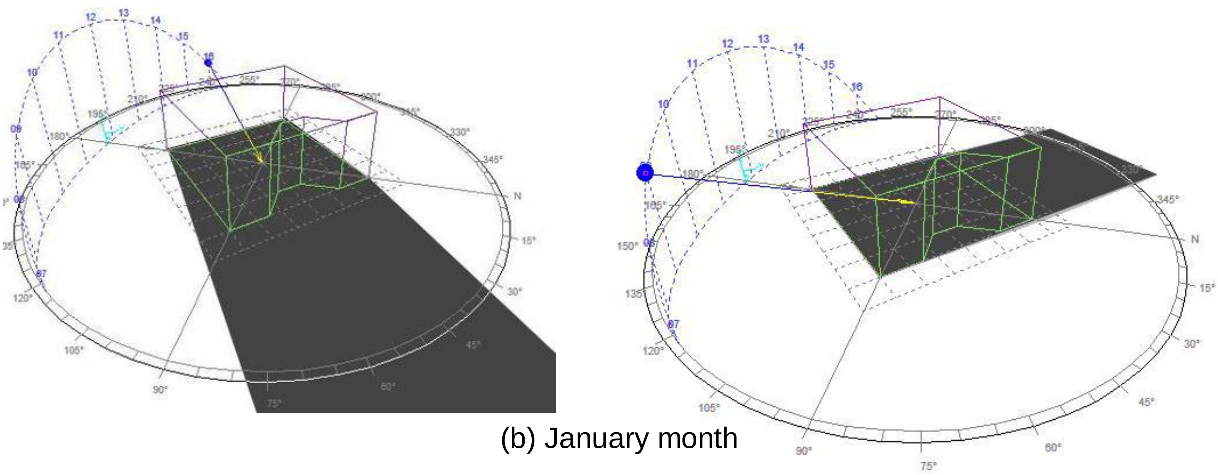
- **Theoretical Results:**

The theoretical study was applied using a software computer package, (Ecotect). This software uses the climatic data to calculate the thermal performance and solar shading techniques for different building orientation. Two different window construction were studied for the summer and winter seasons. First one is without shading devices and second with horizontal shading. The solar shading areas inside the room for different orientation were obtained.

Figures (5-a,b) show the theoretical results for the sun path and the resultant natural lighting areas inside a room without window shading in which the window was oriented to the North – East direction in July and December months. It is noticed for July, (fig. 5-a) the small lighted area inside the room was occurred at the morning. In winter, (fig. 5-b), there is no direct solar radiation penetrates inside the room during the day. For the two cases it is noted that there is no need for window solar shading for the North-East orientation.



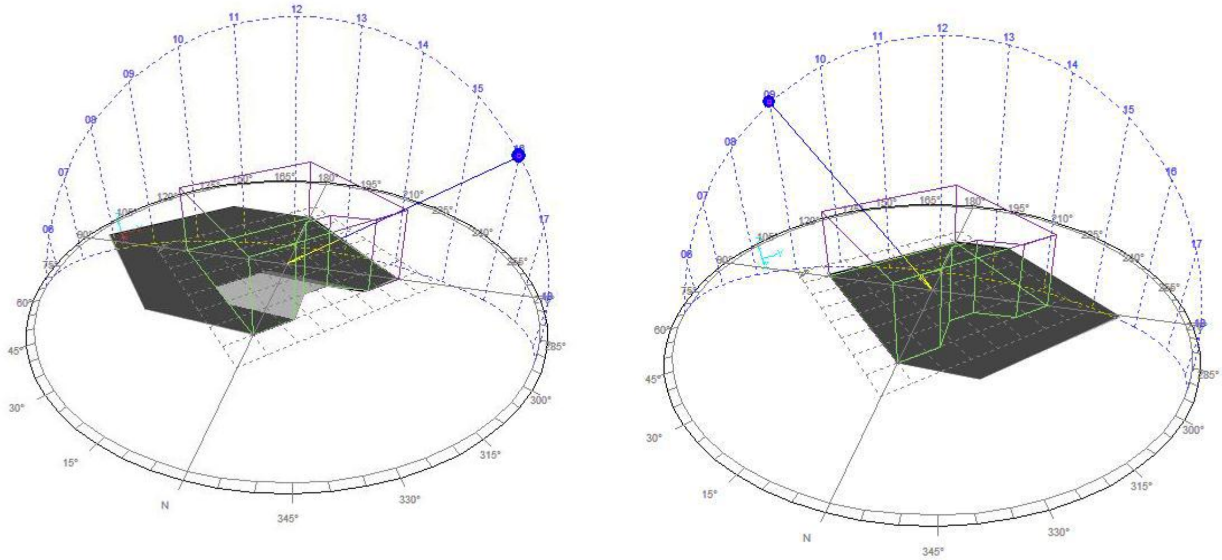
(a) July month



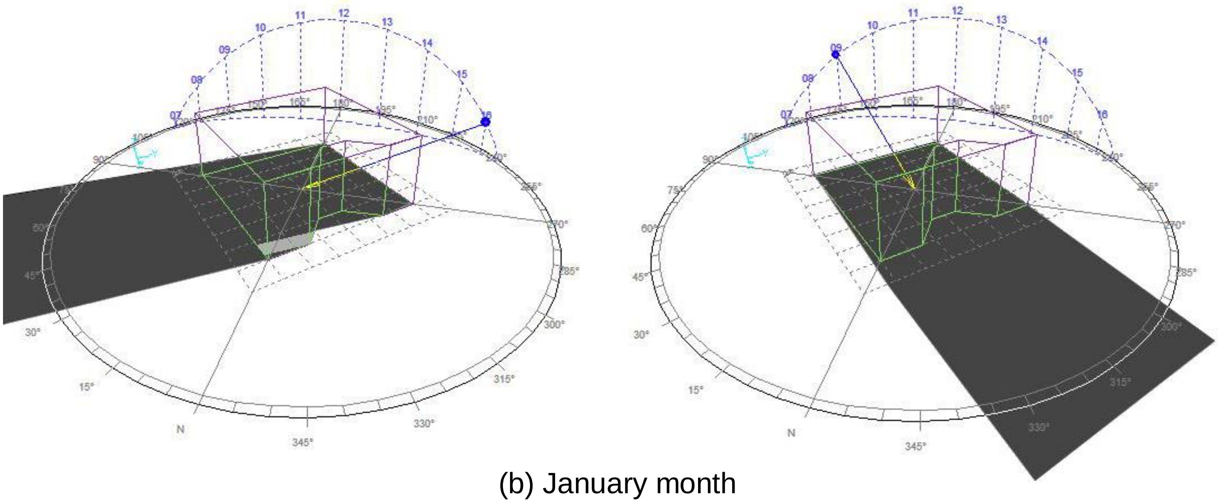
(b) January month

Figs. (5, a-b): The sun path and area of natural lighting inside a room without sun shading for July and December months (window orientation, North-East).

Figures (6-a,b) show the theoretical results for the sun path and the resultant natural lighting areas inside a room without window shading in which the window was oriented to the North – West direction in July and December months. It is noticed for July, (fig6-a) a small lighted area inside the room was occurred after 1:00 p.m. In winter, (Fig. 6-b), there is no direct solar radiation penetrates inside the room during the day. For the two cases it is noted that there is no need for window solar shading for the North-East orientation.



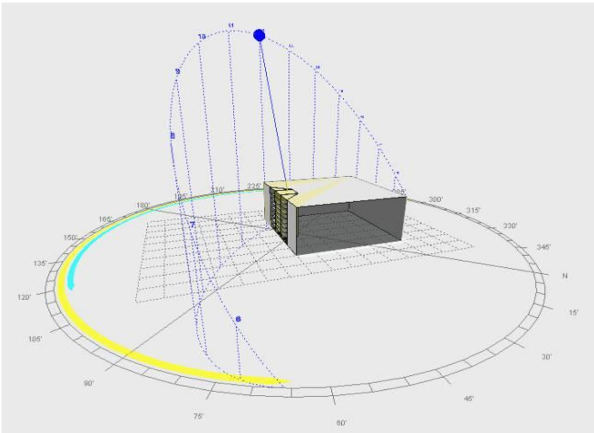
(a) July month



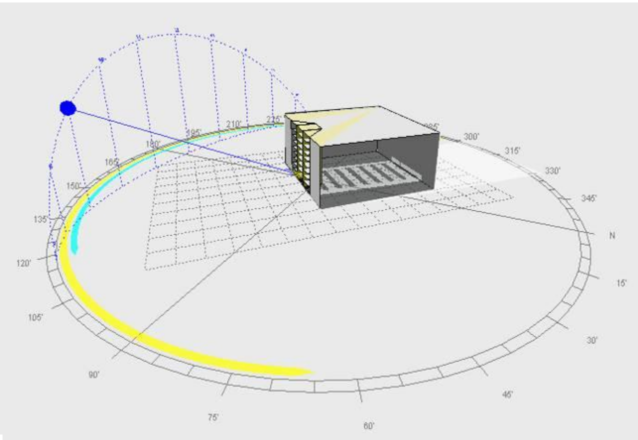
(b) January month

Figs. (6,a-b): The sun path and area of natural lighting inside a room without sun shading for July and December months (window orientation, North-West).

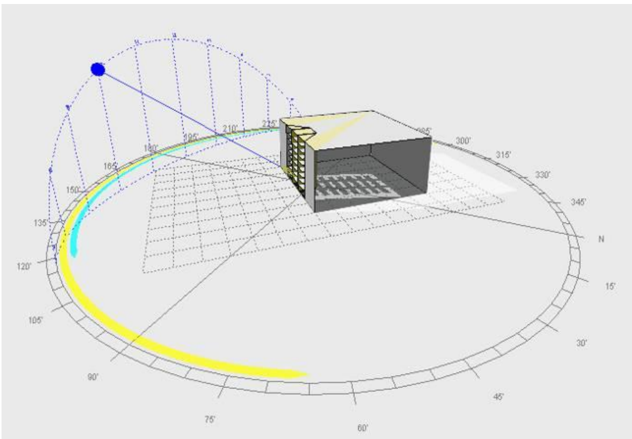
Figures (7-a,b,c,d) show the theoretical results for the sun path and the resultant natural lighting areas inside a room with Horizontal window shading in which the window was oriented to the South-East direction in July and December months. It is noticed that the Shading has more effect in winter than in summer months since the sun track is nearly parallel to the window facade but in winter the sun ray incident with a tilt angle with the window during the day.



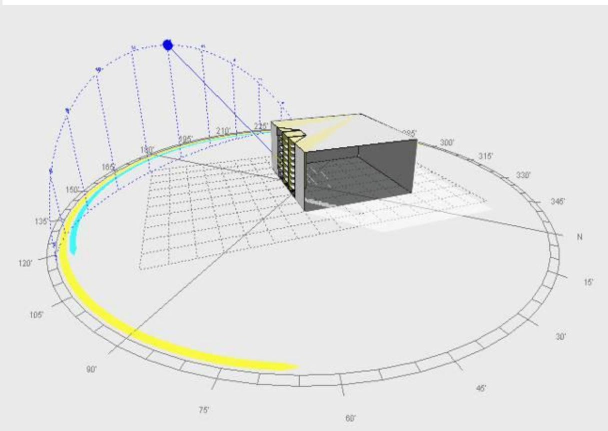
(a) - July month at 12:00 am



(b) - December month at 8:00 am



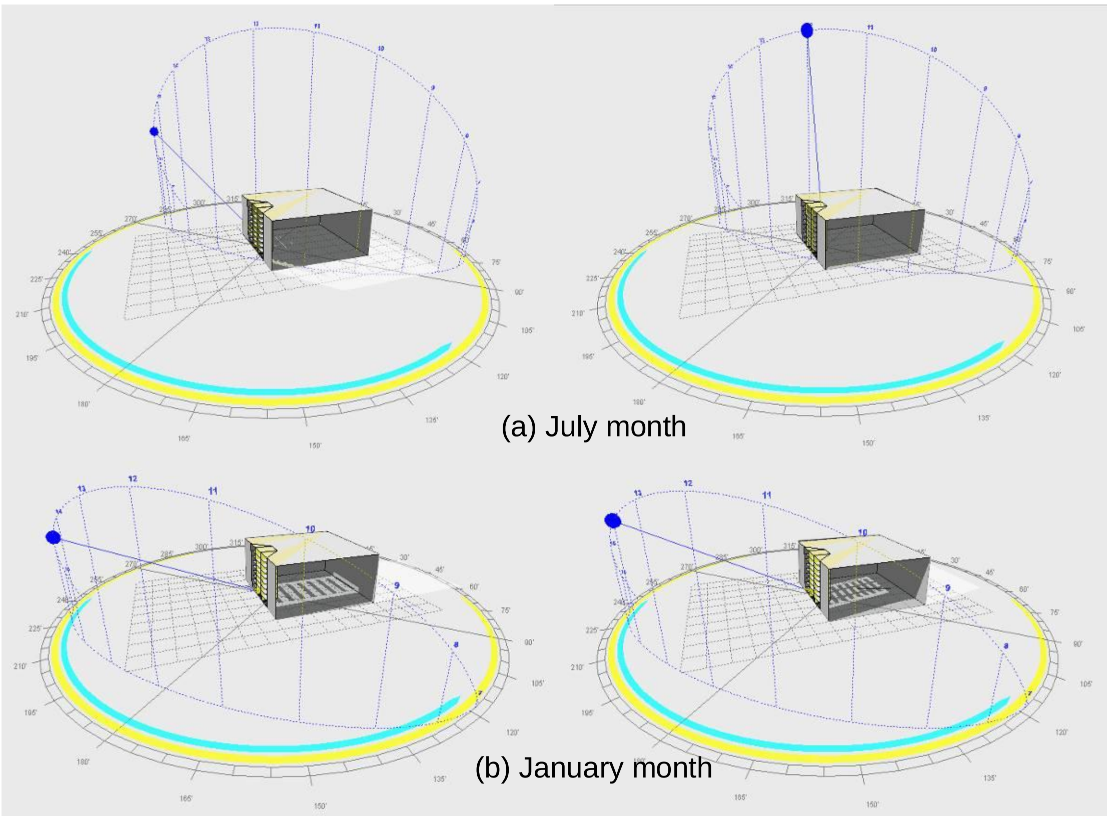
(c) - December month at 10:00 am



(c) - December month at 14:00 am

Figs. (7,a-b): The sun path and area of natural lighting inside a room with horizontal sun shading for July and December months (window orientation, South-East).

Figures (8-a,b) show the theoretical results for the sun path and the resultant natural lighting areas inside a room with Horizontal window shading in which the window was oriented to the South-west direction in July and December months. It is noticed that, as the previous case fig7, the Shading has more effect in winter than in summer months since the sun track is nearly parallel to the window facade but in winter the sun ray incident with a tilt angle with the window during the day.



(a) July month

(b) January month

Figs. (8, a-b): The sun path and area of natural lighting inside a room with horizontal sun shading for July and December months (window orientation, South-West).

Conclusion:

Sustainable design and green building principles are an urgent need for our future and to keep a healthy and balanced relation with our environment. In the architectural design processes we have to follow systematic approaches to grant realize these principles. The architectural program must reflect actual user needs and describe the architectural elements qualitative as well as quantitative. Design considerations must be revised and updated according to the heights standards and latest codes which follow the concept of sustainability. Architectural alternatives, ideas, forms and details must be evaluated according to the prepared design check list to choose the most appropriate design for sustainability.

According to the calculations of the environmental technical study came to the results, that the design of building research center laboratories in 6 October city is well confirmed as energy efficient buildings: choosing building materials, adding thermal insulation, dealing with orientation, modifying internal space depth due to orientation, defined glass area, glass height and glass type; with solar shading devices for giving sufficient natural day light illumination, and using solar energy for producing electric power by photovoltaic cells.

The experimental investigation of air flow around buildings model in smoke tunnel show, that the tilted orientation of the central laboratories with the main façade attains

more air flow for long distances through the building units in which more wall cooling and facility of natural ventilation through inside different units.
Also In case of window façade oriented to North-East, North-West, South-East, or South-West there is no need for shading devices since the sun path is parallel to the widow façade and less sun rays penetrate the window inside the room.

So the end result of technical study came to the conclusion, that this project is standing for energy efficient building, green building and verifying LEED certificate for its –up now – dealing operation in the pre-design stage. Other LEED certificate stages option will be considered through next steps of building process and operation process.

REFERENCES:

For architectural studies

- Brian Griffin, **LABORATORY DESIGN GUIDE**, 2nd edition, architectural press, 2000
- D. Watch, Perkins & Will, **Building Types Basics for Research Laboratories**, JOHN WILEY & SONS, INC, 2001.
- Ernest Orlando Lawrence, **A Design Guide for Energy-Efficient Research Laboratories**, Berkeley National Laboratory, Environmental Energy Technologies Division, Version: 4.0 Date: August 2003

For environmental technical studies

- Achitpon Sasitharanuwata, Wattanapong Rakwichianb, Nipon Ketjoyb, Suchart Yammenc "Performance evaluation of a 10kWp PV power system prototype for isolated building in Thailand", accepted 21 May 2006 Available online 24 July 2006.
- Burgess WA.Ellenbecker MJ, Treitman RD. "Ventilation for control of the work environment" John Wiley &sons, 1989.
- Commission International de l'clearage (lighting), CIE International Organization, 1957.
- Claude L.Robbins "Daylighting - Design & analysis", Van Nostrand Reinhold Company, 1993.
- Egyptian code for improving efficiency of using energy in Building, Part 1: Residential Buildings NO. (1/306) HBRC, Ministry of housing& utilities, 2006.
- Hui, S. C. M., 1997. Overall theraml transfer value (OTTV): how to improve its control in Hong Kong,In *Proc. of the One-day Symposium on Building, Energy and Environment*, 16 October 1997, Shangrila Hotel, Kowloon, Hong Kong, HKIE BS Division/CIBSE/ASHRAE/PolyU, pp. 12-1 to 12-11
- Revised Building Energy Code ,Professor Surapong Chirarattananon, AIT And Mr. Sitphan Kanla, Naresuan University Princess Palace Hotel, Bangkok,13-14 th December 2006

Web sites:

- www.wbdg.org/ design/lableed
  - Whole Building Design Guide- tolat & watch, Using LEED on Laboratory Projects, Daniel Watch and Deepa Tolat, Research Laboratory, Last updated: 03-14-2007
- http://nees.buffalo.edu/docs/labmanual/HTML/
  - Report: laboratory systems, equipment and personnel, Prof. A.M. Reinhorn
- http://books.nap.edu/catalog/9799.html
  - Laboratory Design, Construction, and Renovation: Participants, Process, and Product