Energy Savings in Thermal Insulations for Sustainable Buildings

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ABSTRACT

Energy use is second to staffing in building operating costs. Sustainable technology in the energy sector is based on utilizing renewable sources of energy such as solar, wind, glazing systems, insulation. Other areas of focus include heating, ventilation and air conditioning; novel materials and construction methods; improved sensors and monitoring systems; and advanced simulation tools that can help building designers make more energy efficient choices.

The objective of this research is studying the effect of insulations on energy consumption of buildings in Iraq and identifying the amount of energy savings from application the insulations in buildings. HAP (Hourly Analysis Program) is used to calculate the thermal loads and the amount of energy needed. It is concluded that the use of the thermal insulation in the roof, walls, floors, and double glazing system for windows in building effectively reduces the energy required for air conditioning.

Keywords: sustainable buildings design, energy efficiency technologies, insulations, double glazing system.

وفورات الطاقة في العزل الحراري للابنية المستدامة

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الخلاصة

ياتي استخدام الطاقة في المرتبة الثانية في تكاليف تشغيل المبنى. تستند التكنولوجيا المستدامة في قطاع الطاقة الى استخدام مصادر الطاقة المتجددة مثل الطاقة الشمسية، طاقة الرياح، أنظمة الزجاج، والعزل. هناك مجالات أخرى تتضمن التدفئة، التهوية وتكييف الهواء، أساليب البناء واستخدام مواد جديدة ، وتحسين أجهزة الاستشعار ونظم الرصد، وأدوات المحاكاة المتطورة يمكن أن تساعد مصممي المبنى في اختيار الطاقة الاكثر كفاءة.

يهدف هذا البحث الى دراسة تاثير العوازل في الجدران والسقوف والارضيات والنوافذ على استهلاك الطاقة في الابنية في العراق وتحديد كمية الوفورات في الطاقة الناتجه من تطبيق العوازل في الابنية. تم استخدام برنامج Hourly Analysis Program لحساب الاحمال الحرارية وكمية الطاقة اللازمة. حيث تبين ان استخدام العازل في الجدران والارضيات والسقوف واستخدام النوافذ ذات الزجاج المزدزج في الابنية يقلل بشكل فعال من كمية الطاقة اللازمة للتكييف .

كلمات رئيسية: تصميم الابنية المستدام، تقنيات كفاءة الطاقة، العوازل، نظام الزجاج المزدوج.

1. INTRODUCTION

Sustainable design, green architecture, sustainable constructions, and green buildings these are all new way and method for designing and constructing. The environmental and economical challenges of this era are affecting many sectors. New buildings are being designed, executed and operated by modern technologies which reduces the environmental impact and at the same time leads to reduction in cost especially running costs.

Buildings are large consumers of energy in all countries. In regions with harsh climatic conditions, a substantial share of energy goes to heat and cool buildings. This heating and air-conditioning load can be reduced through many means; notable among them is the proper design and selection of building envelope and its components.

The proper use of thermal insulation in buildings does not only contribute in reducing the required air-conditioning system size but also in reducing the annual energy cost. Additionally, it helps in extending the periods of thermal comfort without reliance on mechanical air-conditioning especially during inter-seasons periods. The magnitude of energy savings as a result of using thermal insulation vary according to the building type, the climatic conditions at which the building is located as well as the type of the insulating material used. The question now in the minds of many building owners is no longer should insulation be used but rather which type, how, and how much.

2. RESEARCH OBJECTIVE

The objective of this research is to identify the potential savings in energy for Building by using insulations in walls, floors, roof, and windows. In order to calculate the energy savings in building, HAP 4.7 (Hourly Analysis Program) from Carrier is used to calculate the thermal loads on two stages:

1. Building without insulations.
2. Building with insulations.

The main objectives of this research are:

1. Identifying the potential quantitative savings in energy from the application of insulations in green house.
2. Studying the effect of sustainable energy technologies systems in Buildings.

3. SUSTAINABILITY

The concept of sustainability in building and construction has evolved over many years. The initial focus was on how to deal with the issue of limited resources. More recently, an appreciation of the significance of non-technical issues has grown. It is now recognized that economic and social sustainability are important, as are the cultural heritage aspects of the built environment. Sustainable design concept can be divided into following aspects, **Jain et al., 2013**:

1. Sustainable site planning, preservation of site character, erosion, and sedimentation.
   Buildings envelop design, optimum design as per climate conditions and energy conservation building codes.
2. Ecologically sustainable material which is based on zero or low toxicity reduces adverse environmental impact.
3. Indoor Ambience, ventilation system to meet minimum indoor air ventilation rates.

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4. Water and waste management, facilitate efficiency in use of water resources.
5. Integration of renewable energy use of energy efficient fixture, materials and integration of energy sources.

4. ENERGY EFFICIENCY TECHNOLOGIES

Energy needs can be reduced in several ways. Improving the performance of a building's envelope means less heating and cooling energy will be required, so the Heating, Ventilation, and Air Conditioning (HVAC) system can be smaller. High efficiency motors should be specified for all heating, ventilation, and air Conditioning components and heat recovery systems. More efficient lighting designs will reduce both lighting and cooling energy costs ,**Perkins and Stantec, 2003**.

4.1 Glazing System

Double glazing window system is commonly used in buildings of today. There have been many attempts to improve the insulation performance of this system such as low-e coating of glass surface, gas-filling between the glass panes, inserting a thermal breaker made of polyurethane or polyamide in frame, etc.. ,**Song et al., 2005**.

The performance of glazing is dependent on the overall rate of heat flow (U-value or thermal transmittance), Solar Heat Gain Coefficient, and visible transmittance. The U-Factor is a measure of how easily heat is transferred through a material and therefore a lower U-Factor indicates the lower amount of heat transfer through a window (from the interior to the exterior). The Solar Heat Gain Coefficient (SHGC) is the fraction of solar heat that enters through a glazing system and becomes heat. Visible transmittance (VT) is the percentage of the visible spectrum that is transmitted through glazing. For example, when daylight is a desired goal, glazing with a high VT is preferable ,**Perkins and Stantec, 2003**.

Double-glazing can substantially reduce the U-value of the glazed area of a building and as such it has become popular. However, double-glazing units are composed of a number of components as opposed to single sheets of glass. Double-glazing units are composed of a number of different materials, including glass, spacer bar, desiccant and sealant. The ultimate properties, qualities and Life time of any double-glazing units depends to a large extent on the type and quality of the individual components and the excellence of their manufacture, **Garvin and Wilson, 1998**.

In the UK the majority of PVC-U and aluminum frames are drained and ventilated. However, timber and steel windows are more commonly fully bedded. Examples of both types of system are shown in **Fig. 1** and **Fig. 2**, **Garvin and Wilson, 1998**.

4.2 Insulation

Well-insulated building envelopes are primary considerations in comfort and sustainability. Insulation helps to protect a building’s occupants from heat, cold, and noise; in addition, it reduces pollution while conserving the energy needed to heat and cool a building. The comfort and energy efficiency of a home and, to a lesser degree, an office depend on the thermal resistance (R value) of the entire wall, roof, or floor (i.e., whole-wall R value), not just the R-value of the insulation. Techniques such as advanced framing increase the wall area covered by insulation, thereby increasing the whole wall’s effectiveness. Framing conducts far more heat than insulation, in the same manner that most window frames conduct more heat than double-paned glass. An additional layer of rigid insulation between framing and exterior sheathing can help improve the whole-wall R-value by insulating the entire wall, and not just the clear space,**Kubba, 2009**.

According to **Mohsen and Akash,2001**, the heating load was calculated for a typical single house using different insulation materials. It was shown that the energy saving up to 77% can be achieved when polystyrene is used for both wall and roof insulation.

Al-Homoud, 2004, summarized the benefits for using thermal insulation in buildings, as follows:

1. A matter of principle: Using thermal insulation in buildings helps in reducing the reliance on mechanical/electrical systems to operate buildings comfortably and, therefore, conserves energy and the associated natural resources.
2. Economic benefits: An energy cost is an operating cost, and great energy savings can be achieved by using thermal insulation.
3. Environmental benefits: The use of thermal insulation.
4. Thermally comfortable buildings: The use of thermal insulation in buildings extends the periods of indoor thermal comfort especially in between seasons.
5. Reduced noise levels.
6. Building structural integrity.
7. Vapor condensation prevention: Proper design and installation of thermal insulation helps in preventing vapor condensation on building surfaces.
8. Fire protection.

American Society of Heating, Refrigerating and Air Conditioning Engineers (2001) mentioned building thermal insulation, which fall under the following basic materials and composites:

1. Inorganic Materials
   - Fibrous materials such as glass, rock, and slag wool.
   - Cellular materials such as calcium silicate, bonded perlite, vermiculite, and ceramic products.
2. Organic Materials
   - Fibrous materials such as cellulose, cotton, wood, pulp, cane, or synthetic fibers.
   - Cellular materials such as cork, foamed rubber, polystyrene, polyethylene, polyurethane, polyisocy-anurate and other polymers.
3. Metallic or metalized reflective membranes: These must face an air-filled, gas-filled, or evacuated space to be effective.

Fig. 3 shows a graphical comparison of the thermal resistances of 5 cm thickness for common building insulation materials. Concrete block is not considered as an insulating material. However, it was included in the figure as a reference (no insulation case) for comparison purposes only.

5. CASE STUDY

The case study evaluates the impacts of high quality insulation in energy consumption in single-family home. In this study a typical Iraqi house layout is considered for a single family. The consists of two floors ground and first floor with a total plot area about 200 square meters having four rooms and two bathrooms one in each floor.

Assumptions:
Air conditioning system consists of package unit and all house walls, roofs and floors without insulations in home.

1. Glass considered single layer with 4 mm thick for windows and doors.
2. The Air Conditioning (AC) plans layout shown in **Fig. 4.**
3. Air Conditioning work 7 months from (April to October).
4. Ordinary bricks used for non-insulated house and insulated concrete block used for insulated house.

5.1 Energy Baseline Usage for Non-insulated House

In order to calculate the efficiency of the new technologies used for sustainable house design, the baseline energy consumption of air conditioning use should be calculated.

Baseline energy consumption of the air condition of the house in the case that the house has not used insulation in the walls, roofs and floors, and windows HAP 4.7 (Hourly Analysis Program) from Carrier is used to calculate the thermal loads. So, What Is HAP?

Carrier's Hourly Analysis Program is two powerful tools in one package. HAP provides versatile features for designing HVAC systems for commercial buildings. It also offers powerful energy analysis capabilities for comparing energy consumption and operating costs of design alternatives. By combining both tools in one package significant time savings are achieved. Input data and results from system design calculations can be used directly in energy studies.

HAP is used to calculate the thermal loads and the amount of energy needed through the introduction of country specific information such as climate, latitude and longitude, spaces dimensions and materials used in walls, floors and roofs. Hap calculated thermal loads and provides the equivalent of the amount of cooling by type of cooling plants used.

Enter the information for each space in the house such as the name of the space, floor area, room lighting, the number of people, walls and windows areas of space exposed to sun radiation, roof area if exposed to sun radiation as shown in **Fig.5**.

After completing the introduction of all information about spaces of house then choosing the AC plant type and specifications required. HAP program analyzes and calculates the thermal loads and the monthly amount of energy required for a period of 7 months in kilowatt. hour (kw.h) as shown in **Table 1.** The results show that the total amount of energy for non-insulated house =24989 kw. h/year.

5.2 Application of Insulation

Majority of insulation in buildings is for thermal purposes, the term also applies to acoustic insulation, fire insulation, and impact insulation. Thermal insulation in buildings is an important factor to achieving thermal comfort for its occupants. Insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling systems. It does not necessarily deal with issues of adequate ventilation and may or may not affect the level of sound insulation. In a narrow sense insulation can just refer to the insulation materials employed to slow heat loss, such as: cellulose, glass wool, rock wool, polystyrene, urethane foam, vermiculite, perlite, wood fiber, plant fiber (cannabis, flax, cotton, cork, etc.).

For the purpose of insulation the home, insulated concrete block with polystyrene thick 10 inches used instead of ordinary bricks for walls with 0.5 inch gypsum plaster and 0.5 inch cement plaster so the overall thermal transmittance (U-Value) become 0.085 British temperature units / Fahrenheit x foot square x hour (Btu/ F ft^2 h). roofs consist of 0.5 inch gypsum plaster, 8 inches concrete, 0.5 inch asphalt sheathing, 2 inches R7 board insulation, 4 inches sand and 1.5 inches cement tiles so the overall U-Value become 0.06 Btu/ F ft^2 h. Double glazing 1/4 inch grey reflective outer glaze and 1/4 inch clear with 1/2 inch air space used for windows. **Fig.6** shows the roof, wall, floor, and windows layers.

When insulated the walls, roofs, floors and windows the thermal transmittance U-value become less than from non-insulated be. **Fig. 7** shows the U-Value for non-insulated wall and **Table 2** shows the U-Values calculated by HAP. After completing the introduction of all information about insulated spaces of House then choose the Air Conditioning plant type and specifications required. HAP program analyzes and calculates the thermal loads and the monthly amount of energy required for a period of 7 months in (kW.h) (see **Table 3**).

The results show the total amount of energy for insulated house =16874 kW.h/year Yearly Savings of air conditioning will be 24989 – 16874 = 8115 kW.hr/year

6. CONCLUSION

The following points have been identified as the overall conclusions of the research:

1. The Sustainable design should seek to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. Integration of architecture and technology can alleviate sustainability in a great way.
2. The cost of such green buildings may be higher by 5-10% than that of conventional building, it will result in 30-40% energy saving and the excess cost can be recovered within 3-4 years. The incorporation of sustainable features should be made mandatory through separate Bye laws for energy efficient buildings to conserve depleting resources and to reduce the overall negative impact of development on the environment.
3. Wall and roof insulation are recommended for buildings in all climates for more thermally comfortable space and, therefore, less energy requirements. Insulation helps in reducing conduction losses through all components of the building envelope. However, roof insulation is generally more critical than walls and should be given more attention.
4. The use of the thermal insulation of the roof, walls, floors, and double glazing system for windows effectively reduces the energy required for air conditioning can arrive where rationalization in energy consumption to about 32%.

7. RECOMMENDATIONS

1. Sectors of urban planning and environment in Iraq must be responsible to develop a national environmental strategy within the concept of sustainable development and issuance of new laws to construction by participation of the planning departments of cities and municipalities in the provinces and the implementation of these strategies during the next stage.
2. Proper treatment of building envelopes can significantly improve thermal performance especially for envelope-load dominated buildings, such as residences. Therefore, the proper selection and treatment of the building envelope components can significantly improve its thermal performance.

3. Designer is important joint in the development of the project in order to defend their own ideas, to clarify the reasons, high-performance projects.
4. Legislation of Determinants relating to the use of renewable energy systems in buildings and urban communities and modify construction systems to include special legislation to energy-saving systems.

REFERENCES

AL-Homoud, M, S., 2004, *Performance Characteristics and Practical Applications of Common Building Thermal Insulation Materials*, Journal: Building and Environment, Vol. 40, No. 3, p.p. 353-366.

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), 2001, *Handbook of Fundamentals*, Chapter 23, USA.

Perkins and Stantec, 2003 ,*Sustainable Building Design Principles, Practices & Systems: A Study for BUILDSMART Program*, Metro Vancouver Body, Canada.

Garvin, S, L.; and Wilson, J, 1998, *Environmental Conditions in Window Frames with Double-Glazing Units,* Journal: Construction and Building Materials, Vol. 12, No. 5, p.p. 289-302.

Jain, S; Bhadouria, A., S; and Khare, A, 2013, *Sustainability in Building Design: Integrating Architecture with Technology to Achieve Energy Efficiency*, Special Issue of International Journal of Sustainable Development and Green Economics (IJSDGE), Vol. 2, No.1, p.p. 33-39. ISSN No.: 2315-4721

Kubba, S, 2009, *LEED® Practices, Certification, and Accreditation Handbook*, Elsevier Publishing, USA, ISBN: 978-1-85617-691-0.

Mohsen, M, S.; and Akash, B, A., 2001,*Some Prospects of Energy Savings in Buildings*, Journal: Energy Conversion and Management, Vol. 42, No.11, p.p. 1307-1315.

Song, S,Y; Jo, J, H; Yeo, M,S; Kim, Y,D; and Song. K,D, 2005,*Evaluation of Inside Surface Condensation in Double Glazing Window System with Insulation Spacer: A Case Study of Residential Complex*, Journal: Building and Environment, Vol. 42, No. 2, p.p. 940-950.

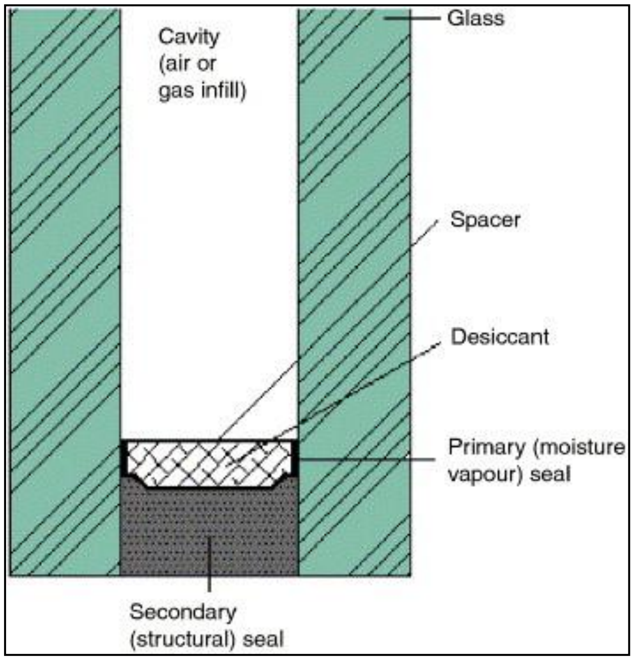


Figure 1. Cross section of a dual sealed double glazing unit,Song et al., 2005.

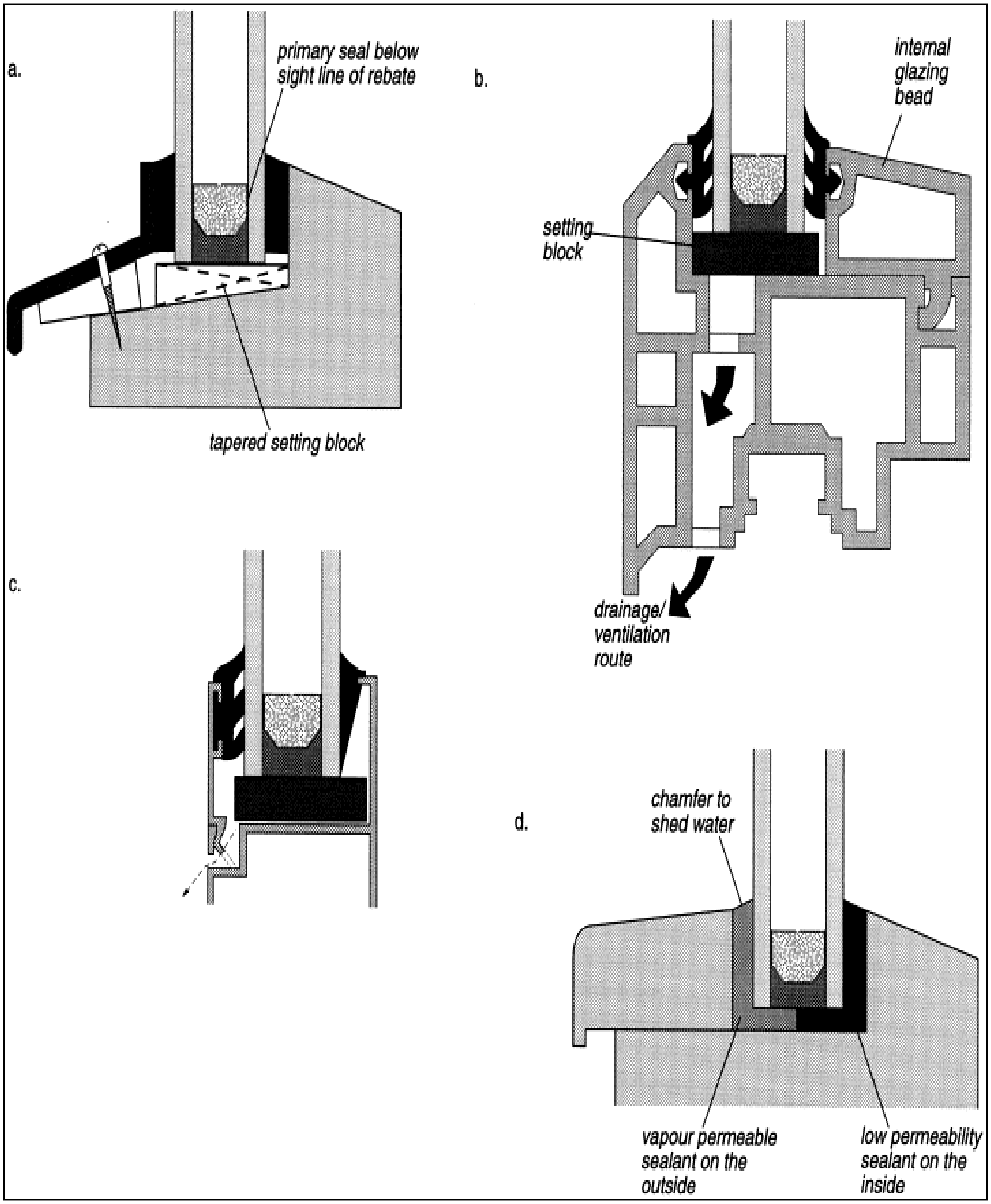


Figure 2. Drained and ventilated and fully bedded window frames. (a) Timber; (b) PVC; (c) aluminum; (d) timber fully bedded, Garvin and Wilson, 1998.

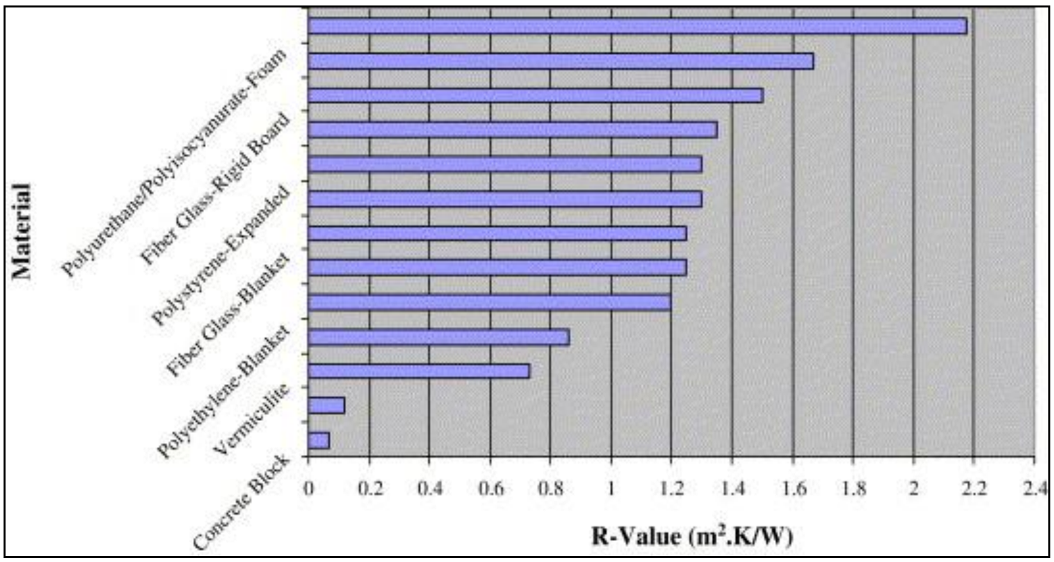


Figure 3. Thermal resistances (5cm thickness) of common building insulation materials (Concrete block is added for comparison purposes), Al-Homoud, 2004.

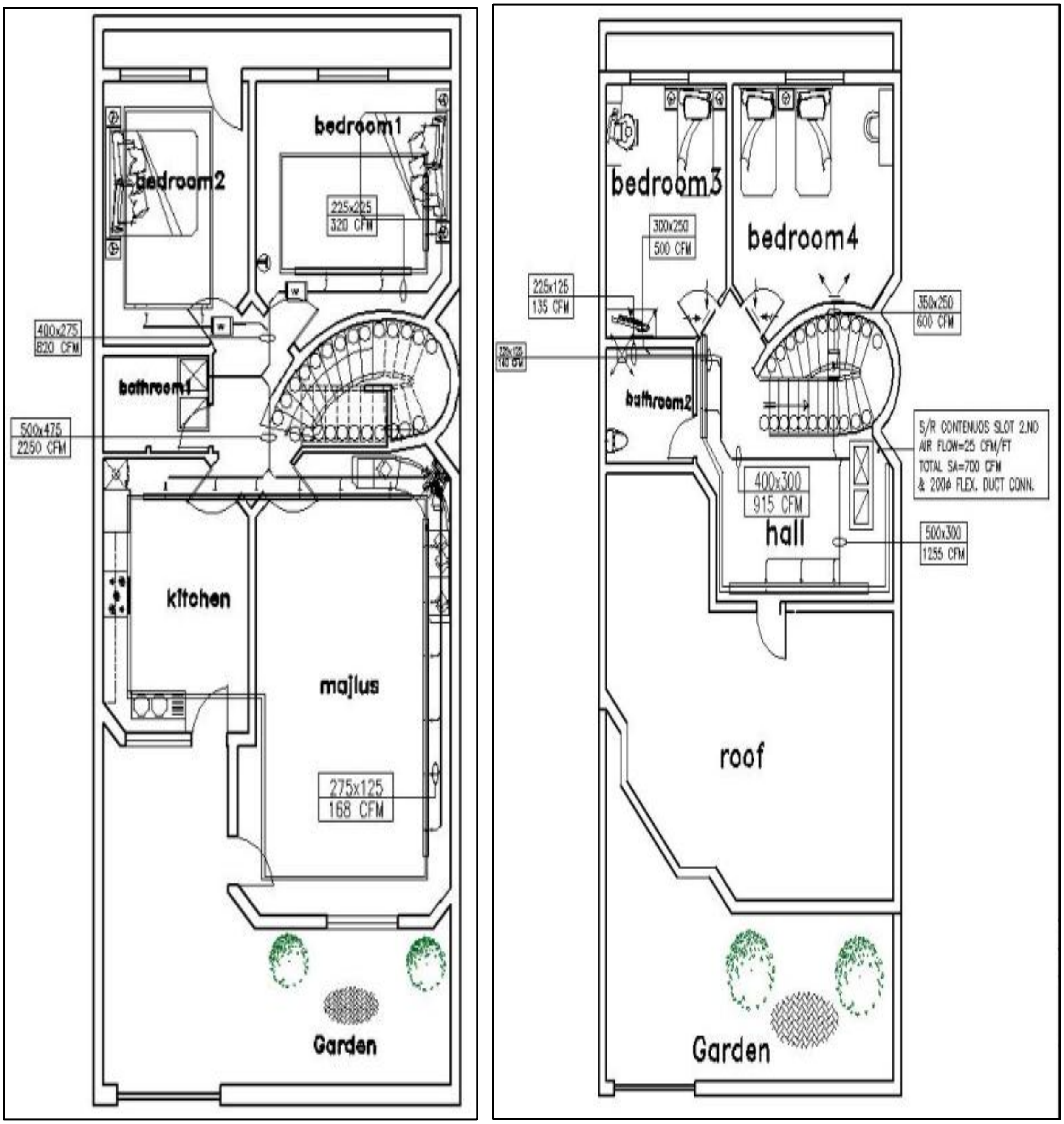
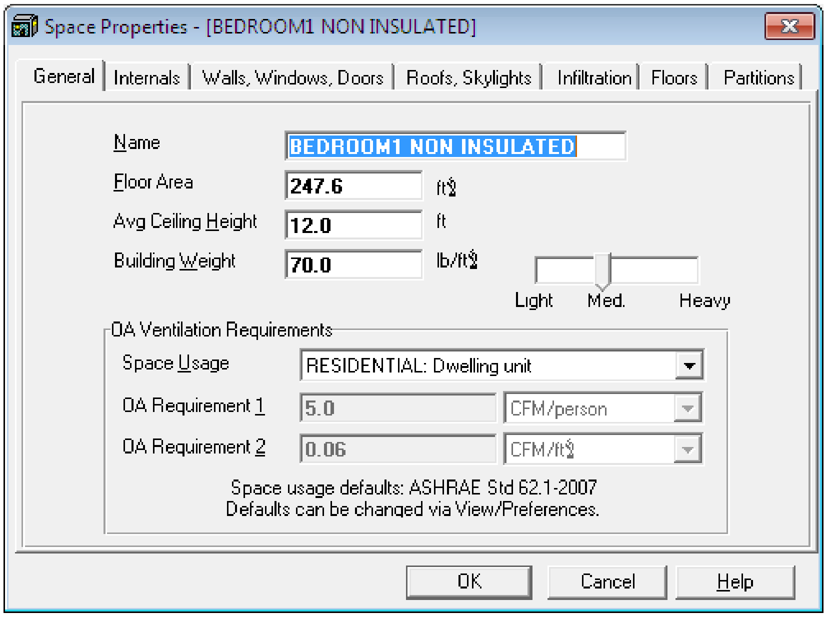


Figure 4. Air Conditioning plans layout.



.**Figure 5.** HAP space properties.

Table 1. Monthly simulation results for non-insulated house package unit.

Month	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Clg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Coil Input (kWh)	Zone Heating Coil Load (kBTU)	Zone Heating Coil Input (kWh)
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0
April	22969	22969	1690	0	0	0	0
May	36201	36201	3068	0	0	0	0
June	44037	44037	4103	0	0	0	0
July	50368	50368	4940	0	0	0	0
August	50220	50220	4915	0	0	0	0
September	42022	42022	3815	0	0	0	0
October	30874	30874	2458	0	0	0	0
November	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0
Total	276690	276690	24989	0	0	0	0

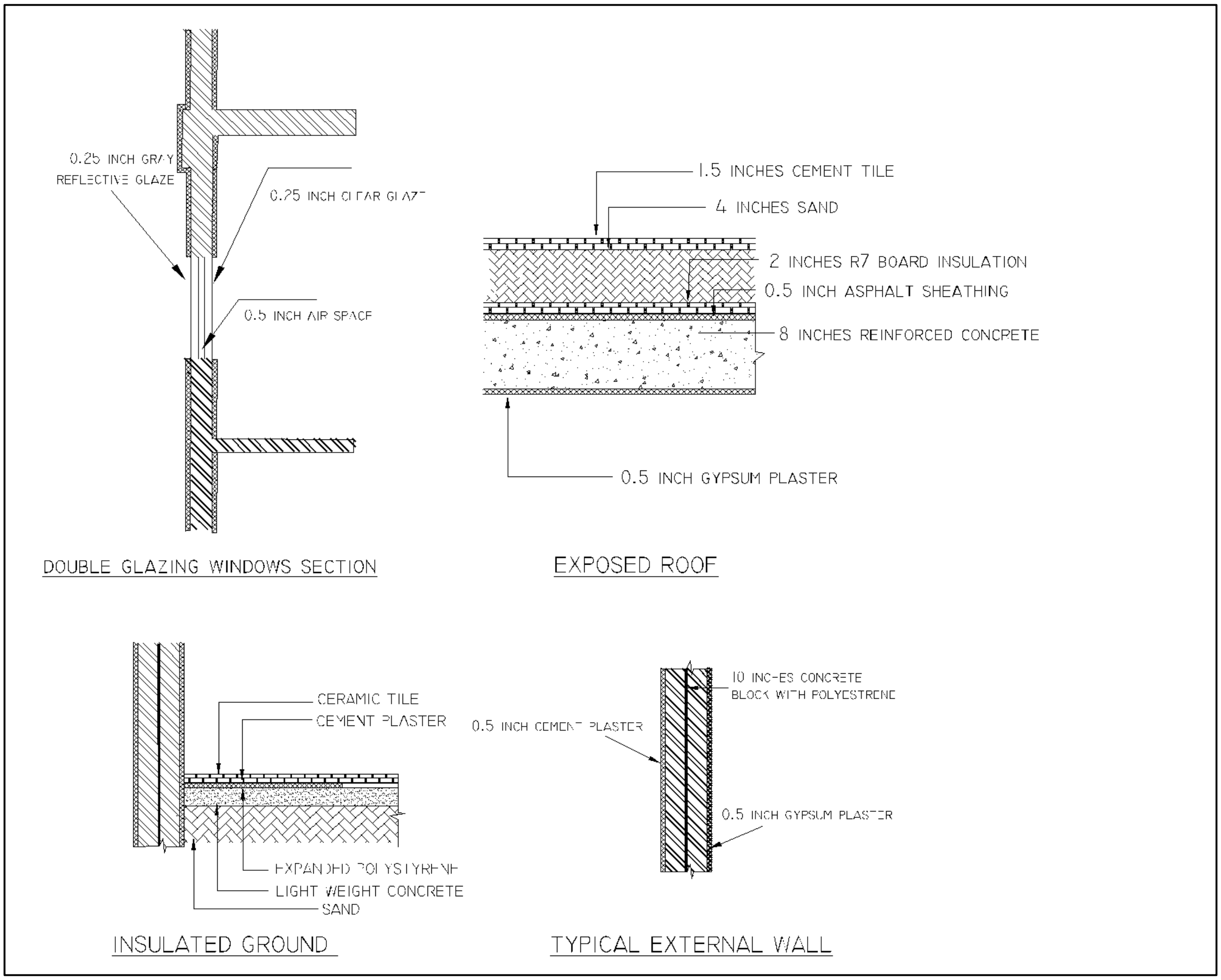


Figure 6. Insulated roofs, walls, floors, and double glazing windows (Researcher).

Table 2. U-Values.

Portion	**U-Value Non-insulated Btu/ F ft^2 h**	**U-Value insulated Btu/ F ft^2 h**
roofs	0.345	0.06
walls	0.301	0.085
windows	1.228	0.717

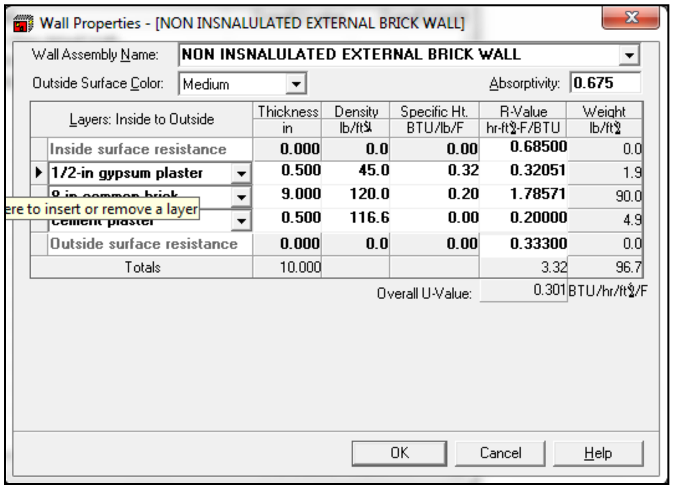


Figure 7. HAP U-Value and R-Values for Non-Insulated wall (Researcher).

Table 3. Monthly simulation results for insulated house package unit.

Month	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Clg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Coil Input (kWh)	Zone Heating Coil Load (kBTU)	Zone Heating Coil Input (kWh)
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0
April	18710	18710	1372	0	0	0	0
May	25253	25253	2136	0	0	0	0
June	28836	28836	2692	0	0	0	0
July	32350	32350	3184	0	0	0	0
August	32322	32322	3173	0	0	0	0
September	27873	27873	2533	0	0	0	0
October	22481	22481	1785	0	0	0	0
November	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0
Total	**187824**	**187824**	**16874**	**0**	**0**	**0**	**0**