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Abstract:

Depletion of energy resources and the effect of their combustion on the environment alongside other factors have made the topic of "Green Building" a major concern and interest worldwide. Green Building, also known as sustainable development, is a practice that delivers energy efficient and environmentally friendly buildings. This involves the whole lifecycle of the building –starting from the site selection, construction, operation, maintenance, renovation and ending with demolition. This results with the reduction of buildings' negative impact on the environment and occupants.

The application of Green Building concepts might be more beneficial for countries with low availability of energy resources. This is true because green buildings are energy efficient; their application reduces the energy demand of the country, and reduces the need for importing energy resources and in turn reduces the burden of the energy bill on the country's economy. But, implementation of Green Building practices, almost always, means additional investment cost is needed. This is one of the main reasons retarding the vast spread of Green Building practices.

At present, little attention is paid for Green Building practices in the construction sector in Jordan. This study examines and determines the investment and operation costs of different thermal insulation designs practiced in Jordan (according to Jordanian national building codes), and the mechanical heating designs required for them. Investment and operation costs for Green Building practices, in terms of thermal insulation and heating, are also determined. And the payback period and the return on investment of implementing these Green Building practices are calculated. The carbon footprints of each of the different thermal insulation designs are also determined and compared in this study.

1: Introduction:

1.1: Overview:

1.1.1: Aims:

This papers aims to provide an understanding of the importance of thermal insulation and its benefits and to encourage investments in it.

1.1.2: Objectives:

The objectives that will facilitate the achievement of the aforementioned aims are:

- Determine the payback period for investing in different thermal insulation designs.
- Determine the payback period for investing in a higher efficiency thermal insulation design combined with replacing mechanical heating systems with solar heating systems.
- Determine the return on investment for investing in different thermal insulation designs.
- Determine the return on investment for investing in a higher efficiency thermal insulation design combined with replacing mechanical heating systems with solar heating systems.
- Determine the carbon footprints of different cases of thermal insulation designs and their corresponding mechanical or solar heating systems.

2: Methodology:

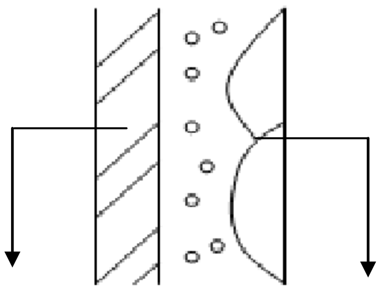
The aims and objectives of this paper are hoped to be achieved through a case study. The case study chosen is a residential house in Al-Kamaliyyah, Jordan.

The house is going to be assigned with different cases of thermal insulation designs according to: first, the traditional way of building in Jordan. Second, the Jordanian Thermal Insulation Code 2002. Third, the Jordanian Thermal Insulation Code 2009. For each case, a design of mechanical heating is then going to be obtained from a local specialist supplier (TechnoHouse) with a specific boiler capacity, radiator units' lengths and system components.

Finally, the house is then going to be assigned with a better thermal insulation design which allows it to be an Eco-house, and a design for a solar heating system is then going to be obtained from a specialist solar systems supplier (Millennium Industries).

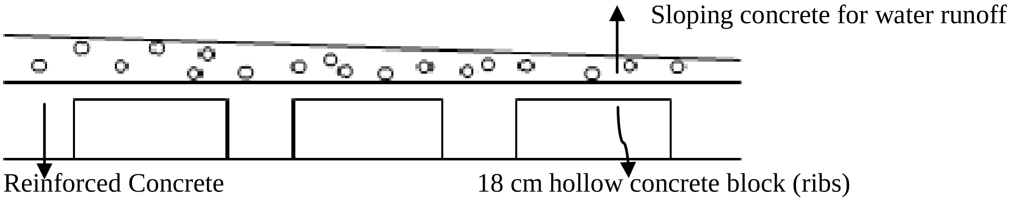
- *Case 1:* traditionally and before there was an obligatory Thermal Insulation Code in Jordan, people used to ignore thermal insulation in buildings in order to avoid the additional investment cost that accompanies it. The following cross sections are typical for roofs and walls in Jordanian traditional buildings.

Walls:
U-value= 3.34 W/m^2.k



10 cm hollow concrete block 25 cm stone and concrete (facade)

Roofs:
U-value= 2.44 W/m^2.K

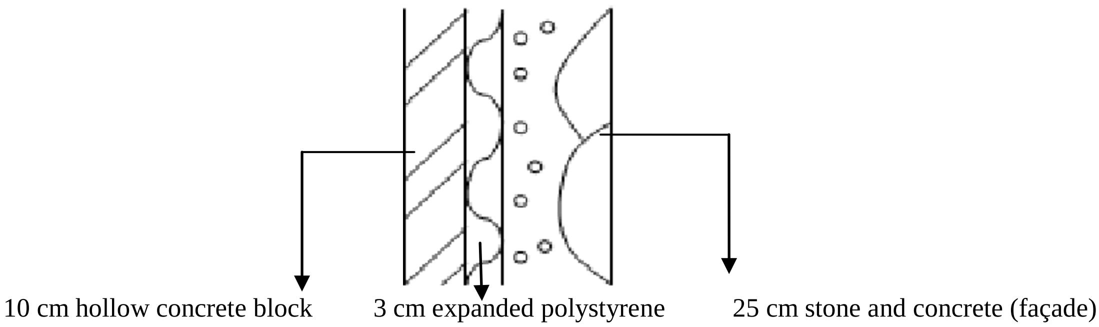


The mechanical heating design that is needed with these cross sections requires a boiler with a thermal output capacity of 200 KW and 71 m of radiator units.

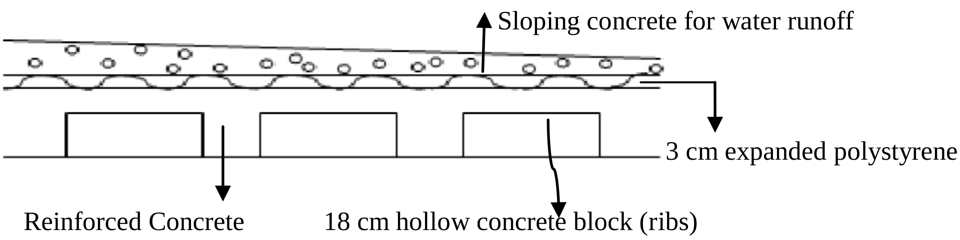
- *Case 2:* the Jordanian Thermal Insulation Code 2002 was introduced by The Jordanian Ministry of Public Work and Housing. This code has restrictions and minimum requirements for thermal insulation to be met in buildings. The code requires walls (including openings) to have a maximum U-value of 1.8 W/m^2.K, and roofs to have a maximum U-value of 1.0 W/m^2.K.

The following cross sections for roofs and walls are typical cross sections that meet the requirements of the Jordanian Thermal Insulation Code 2002.

Walls:



Roofs:

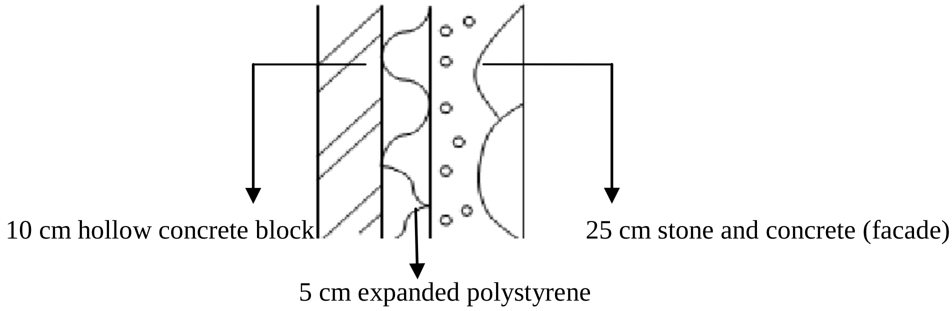


The mechanical heating design that is needed with these cross sections requires a boiler with a thermal output capacity of 95 KW and 36 m of radiator units.

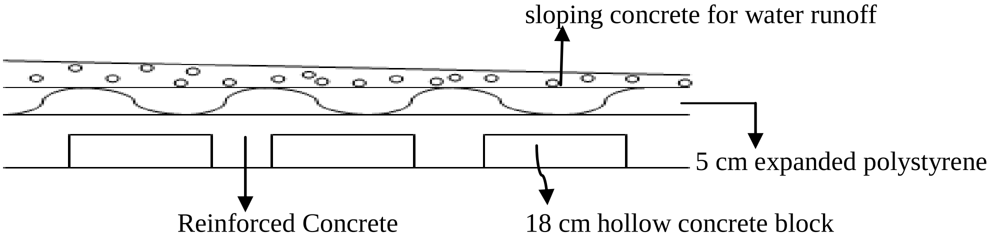
- *Case 3:* the Jordanian Thermal Insulation Code 2009 .This code is an update of the 2002 code and has further restrictions and more efficient minimum requirements for thermal insulation to be met in buildings. The code requires walls (including openings) to have a maximum U-value of 1.6 W/m^2.K, and roofs to have a maximum U-value of 0.55 W/m^2.K.

The following cross sections for roofs and walls are typical cross sections that meet the requirements of the Jordanian Thermal Insulation Code 2002.

Walls:



Roofs:

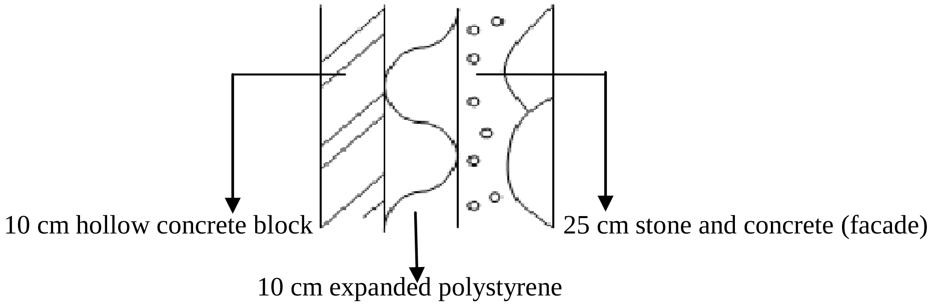


The mechanical heating design that is needed with these cross sections requires a boiler with a thermal output capacity of 78 KW and 30 m of radiator units.

- *Case 4:* for this case, an additional 5 cm of expanded polystyrene boards is going to be added. For roofs, the sloping concrete is going to be replaced by foam concrete (K value= 0.12 W/m.K) and the hollow concrete block ribs are going to be replaced by expanded polystyrene ribs. This will increase the thermal insulation efficiency of the building and will allow for a solar heating system to be sufficient for heating.

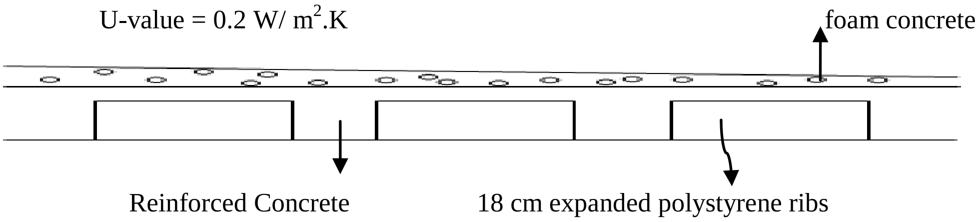
Walls:

U-value = 1.13 W/ m^2.K (including openings)



Roofs:

U-value = 0.2 W/ m^2.K



For the solar heating of the house with the above cross sections, 12 solar collectors and 4 fan coils are needed.

Assumptions and Facts:

- Estimated heated area of the house = 443 m^2 (200 m^2 ground floor, 210 m^2 first floor, 33 m^2 roof)
- Summer design dry bulb temperature = 36.0 C°
- Winter design dry bulb temperature = 0.6 C°
- Internal temperature = 22.0 C°
- Estimated external walls area of the house = 470 m^2
- Estimated external walls area of the house without the openings = 400 m^2 (15% openings)
- Estimated roof area of the house = 210 m^2
- Same glazing was used for the four cases
- waterproofing is present in all four cases (4 mm asphaltic membrane with reflective layer on roofs)
- Construction time for all four cases is the same
- Heat losses underneath ground floors are assumed to be equal in the four cases
- Maintenance cost of heating systems in the four cases is assumed to be the same
- All four cases have the same geographical location and weather conditions
- All four cases have the same design
- Supervision conditions are the same for the four cases
- All prices are obtained from specialized contractors and suppliers, and are correct as of august 2010
- Mechanical heating components, design and prices are obtained from TechnoHouse (a leading supplier in the Jordanian market for heating solutions)
- Solar heating components, design and prices are obtained from Millennium Energy Industries (www.milleniumenergy.co.uk) and have the following specific assumptions and facts:
  - Average tilt angle factor = 1.424
  - Two fan coils are needed to heat each floor (four fan coils in total)
  - Hot water supply of the house = 17.4 KWh/day
  - 30% heat load was added to account for losses
  - Total heating load of the house = 30.61 KW
  - 12 solar panels are needed
- The three mechanical heating systems and the solar heating system are assumed to have the same efficiency
- Thermal insulation components prices are obtained from “Ahmad Khadro Engineering and Contracting Company” and are
  3.5 JD/ m^2 for the 3 cm polystyrene boards, 5.5 JD/ m^2 for the 5 cm polystyrene boards, and 7 JD/ m^2 for the 10 cm polystyrene boards
- Unit cost of hollow concrete ribs (including transportation, lifting and installing) = 0.42 JD/ unit (Ahmad Khadro Engineering and Contracting Company)
- Unit cost of expanded polystyrene ribs (including transportation, lifting and installing) = 0.5 JD/ unit (Ahmad Khadro Engineering and Contracting Company)
- 1 Jordanian Dinar (JD) = 1.41 US dollar ≈ 0.91 GBP
- Diesel price = 0.465 JD/L as of August 12^{th} 2010
- Working lifespan of solar panels is assumed to be the same as the working lifespan of the radiators
- Foam concrete is assumed to cost the same as reinforced concrete
- Fuel consumption for each case (except case 4 as there is no fuel consumption for that case) was estimated according to the average U-value of each case, and the proportion of that of the first case:
  - Case 1: fuel consumption = 20L/m^2 annually (according to the National Energy Researches Centre NERC)
    U-value of walls (including openings) = 3.34 W/ m^2.K
    U-value of roof = 2.44 W/ m^2.K
    Average U-value = 3.34 x (470/680) + 2.44 (210/680) = 3.06 W/ m^2.K
    (470 being the external walls area, 210 being the roof area, and 680 being the total area of the two)

- Case 2:
  U-value of walls (including openings) = 1.8 W/ m^2.K
  U-value of roof = 1.0 W/ m^2.K
  Average U-value = 1.8 x (470/680) + 1.0 x (210/680) = 1.55 W/ m^2.K
  Fuel consumption = (1.55 W/ m^2.K x 20 L/m^2) / 3.06 W/ m^2.K = 10.13 L/m^2
- Case 3:
  U-value of walls (including openings) = 1.6 W/ m^2.K
  U-value of roof = 0.55 W/ m^2.K
  Average U-value = 1.6 x (470/680) + 0.55 x (210/680) = 1.28 W/ m^2.K
  Fuel consumption = (1.28 x 20) / 3.06 = 8.37 L/m^2

3: Calculations and Results:

Case 1: Traditional buildings (no thermal insulation):

- Total mechanical heating cost = 15305 JD
- Fuel Consumption = 20L/ m^2 annually (according to the National Energy Researches Centre NERC)
  Annual fuel consumption = 20 x 443 m^2 = 8860L/ year
  Annual fuel cost = 8860 x 0.465 JD/L = 4119.9 JD/year
- Carbon footprint: 26 tons of CO_2 annually (obtained from www.carbonify.com carbon calculator)
- Thermal insulation additional cost = zero

Total investment cost for thermal insulation and heating = 15305 JD.

Case 2: Jordanian Thermal Insulation Code 2002

- Total mechanical heating cost = 10070 JD
- Fuel Consumption = 10.13 L/ m2 annually
  Annual fuel consumption = 10.13 x 443 = 4488 L/year
  Annual fuel cost = 4488 x 0.465 JD/L = 2086.92 JD/year
- Carbon footprint: 13.21 tons of CO2 annually (obtained from www.carbonify.com carbon calculator)
- Thermal insulation additional cost = 2135 JD

Total investment cost for thermal insulation and heating = 12205 JD

Case 3: Jordanian Thermal Insulation Code 2009

- Total mechanical heating cost = 9139 JD
- Fuel Consumption = 8.37 L/ m^2 annually
  Annual fuel consumption = 3708 L year
  Annual fuel cost = 3708 x 0.465 JD/L = 1724.22 JD/year
- Carbon footprint: 10.92 tons of CO_2 annually (obtained from www.carbonify.com carbon calculator)
- Thermal insulation additional cost = 3355 JD

Total investment cost for thermal insulation and heating = 12494 JD

Case 4: Eco-House (Al-Kamaliyyah Residence)

- Solar heating cost = 11880 JD
- Annual fuel consumption = zero
  Annual fuel cost = zero
- Carbon footprint: zero CO_2 emissions
- Thermal insulation additional cost = 3249.4 JD

Total investment cost for thermal insulation and heating = 15129.4 JD

Payback period results:
Applying case 2 over case 1 saves money at investment so the payback period is zero.
Applying case 3 over case 1 saves money at investment so the payback period is zero.
Applying case 4 over case 1 saves money at investment so the payback period is zero.
Payback period for investing in case 3 over case 2:
(12494 – 12205) / (2086.92 – 1724.22) = 0.8 years = 10 months
Payback period for investing in case 4 over case 2:
(15129.4 – 12205) / (2086.92 – zero) = 1.4 years = 17 months
Payback period for investing in case 4 over case 3:
(15129.4 – 12494) / (1724.22 – zero) = 1.52 years = 19 months

Return on investment results:
-ROI of case 2 over case 1:
There is no additional investment and operation cost in applying case 2 over case 1 in the three identified periods (1, 3 and 5 years).
-ROI of case 3 over case 1:
There is no additional investment and operation cost in applying case 3 over case 1 in the three identified periods (1, 3 and 5 years).
-ROI of case 4 over case 1:
There is no additional investment and operation cost in applying case 4 over case 1 in the three identified periods (1, 3 and 5 years).
-ROI of case 3 over case 2:
There is no additional investment and operation cost in applying case 3 over case 2 in the three identified periods (1, 3 and 5 years).
-ROI of case 4 over case 2:
Total investment + fuel cost of case 2 for 1 year = 12205 + 2086.92 = 14291.92 JD
Total investment + fuel cost of case 2 for 3 years = 12205 + (3 x 2086.92) = 18465.76 JD
Total investment + fuel cost of case 2 for 5 years = 12205 + (5 x 2086.92) = 22639.6 JD
$ROI_{(1\ year)}$= (14291.92 – 15129.4) / 15129.4 = -5.54%
$ROI_{(3\ years)}$= (18465.76 – 15129.4) / 15129.4 = 22.05%
$ROI_{(5\ years)}$= (22639.6 – 15129.4) / 15129.4 = 49.64%
-ROI of case 4 over case 3:
Total investment + fuel cost of case 3 for 1 year = 12494 + 1724.22 = 14218.22 JD
Total investment + fuel cost of case 3 for 3 years = 12494 + (3 x 1724.22) = 17666.66 JD
Total investment + fuel cost of case 3 for 5 years = 12494 + (5 x 1724.22) = 21115.1 JD
$ROI_{(1\ year)}$= (14218.22 – 15129.4) / 15129.4 = -6.02%
$ROI_{(3\ years)}$= (17666.66 – 15129.4) / 15129.4 = 16.77%
$ROI_{(5\ years)}$= (21115.2 – 15129.4) / 15129.4 = 39.56%

4: Conclusions:

It was concluded that choosing a high efficiency thermal insulation design, such as the one used in case 4, combined with the replacement of mechanical heating system with solar heating system should be the most favourable choice. Investing in such case not only saves operational costs on the long run, as no fuel is needed for the solar heating system, but also saves money in the initial investment cost if compared with a case where no thermal insulation at all is used. Savings on initial investment cost come from the high cost of mechanical heating that would be needed for adequate heating where no thermal insulation is used. Moreover, even when investing in this case results in additional initial investment cost when compared to the earlier mentioned cases 2 & 3, the payback period can be as short as 17 months after which savings from eliminating fuel cost will be earned, and the return on investment can be as high as 49.64% over a period of 5 years. This will also save significant amounts of CO_2 emissions and will eliminate the carbon footprint associated with the heating system.

It was also concluded that investing in thermal insulation can result in savings on initial investment cost. Comparing the initial investment costs for thermal insulation and mechanical heating of the earlier mentioned cases 2 & 3 with that of a case where no thermal insulation is used shows that significant savings can be earned. Additionally, savings due to less fuel needed for mechanical heating operation can be attained. Furthermore, when extra initial investment cost is needed for additional thermal insulation, the payback period can be as short as 10 months, after which savings from reducing the annual fuel cost can be earned. This will also reduce the carbon footprint by reducing the CO_2 emissions associated with the mechanical heating system.

References:

[1] Ministry of Public Works and Housing (2002), *Thermal Insulation Code,* Ministry of Public Works and Housing.

[2] Ministry of Public Works and Housing (2009), *Thermal Insulation Code,* Ministry of Public Works and Housing.

[3] Sab' Al Eish A. (1990). *Directory for thermal insulation materials of buildings* (دليل مواد العزل الحراري للمباني), Amman: Royal Scientific Society, Building Research Centre.