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Improve energy efficiency by applying passive design (envelope) strategies in construction materials in Tehran

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Abstract

To improve envelope design in buildings of Tehran, This paper discusses the baseline energy consumption in midrise buildings of Tehran as a primary factor to approach for envelope design. For this purpose, electricity and gas bills of over ten apartment blocks has been collected randomly in Tehran. This data also will be compared against the official statistics of energy consumption in the country, as there are not any published official figures separately for Tehran. These mentioned apartments based on their construction practices will be divided to three groups of construction, therefore a primary understanding will be gained over energy consumption in buildings by varies construction practices. Furthermore, the findings of this research may be employed for further optimization over the best selected construction practice of this research to optimise energy consumption in midrise buildings in Tehran.

Keywords: Construction practice; Building Envelope;

1. Introduction

Buildings around the world consume in average 40% of energy, and emit same amount of Co2 or greenhouse gases. In many developed countries some compulsory regulations are in force to reduce energy consumption and Co2 emission from buildings. In this region, with abundant fossil fuel resources, buildings, consume more energy and emit more Co2 than the world's average figures.

As Figure 1 shows, natural gas accounts 76% of total final energy consumption in residential sector, and also electricity and oil products by 12%, respectively [**1**].

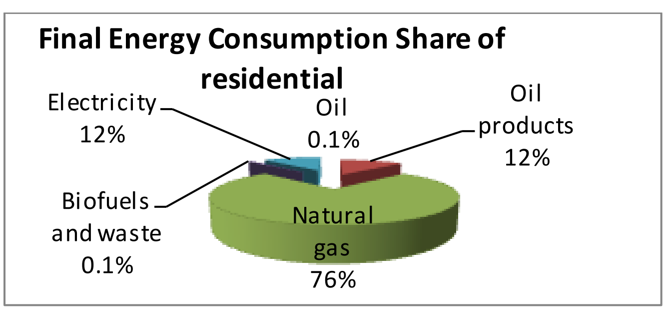

Figure 1, Final energy consumption in residential sector in Iran, source: IEA (2012

In Iran, according to the Iranian energy efficiency organization [**2**], a significant amount of the final energy consumed for heating and cooling in residential buildings, i.e. 76% of total natural gas (for heating) and 25% of electricity (for cooling and heating), however, according to Tehran electricity supplier company [**3**] Tehran's residential sectors consume 35% of the electricity supply in Tehran. In another word, 56% of total final energy in residential sector consumed for heating and cooling loads in Iran and 60% in Tehran respectively [**3**].

Since 2006 to 2013 more than 5.8 million households unit had been built in Iran. On the basis of licenses issued by the municipal building in Tehran in 2011 [**4**], of total residential units about 0.2% for single-story buildings, 0.3% for two-story buildings, 1.1% for three-story buildings, and 4.3% for four-story buildings, and 94% for the five-story buildings [**5**]. Annually more than 179 thousand residential units are built in Tehran, which is more than other cities in the country. Approximately, annually, 19 thousand residential complexes built in Tehran; consequently, in average nine dwelling unit is built in a residential complex [**5**]. According to Khadem, head of Planning and Budget Commission of the City Council, Tehran until 2025 will need 3.4 millions of dwelling units [**6**].

The statistics above show that housing construction in Tehran, in form of mid-high rise buildings and residential complexes, is growing sharply. And also considering the future needs, the construction rate will grow sharply in future too.

Consequently, the aim of this research is to investigate which current construction practice would contribute to energy saving in buildings in this region through the Building Envelope design.

In order to achieve the above aim, this research will take the following stage of studies: (a) identify the energy consumption related to building physic in this region; (b) identify the most efficient local building elements for building envelope.

2. Problem identification and basic principle

Iran's ultimate energy consumption pattern over the last couple of years is inefficient and contributes towards the excessive consumption of fossil fuels which produces several quantities of pollutants and greenhouse gases [**7**]. Low price of energy and high subsidies represent an effective incentive for inefficient energy consumption pattern and accelerate energy consumption and environmental pollutions [**7**]. In Tehran, as a region with hot summers and cold winters (semi-arid climate), Buildings require to apply a comprehensive passive design that not only to prevent heat loss (thermal loss) by implementing proper insulation, but reduce the required heat or cold load by providing heating and cooling from the natural environment. Various energy statistics around the world verify that energy consumption in Iran is far higher than the world average. It is also unknown how the construction practices (e.g Materials selection and design) and other factors (e.g. economical and socio-cultural), share the high energy consumption's role in the country.

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In Iran, as mentioned above, low price of energy and heavy energy subsidies are the main reasons for high energy consumption in buildings during operational phase. On the other hand, the other parameter accounts for building design in design phase.

It is unknown how the energy efficiency is considered in architectural design in the country. Although there is chapter 19 to address a couple of building envelope design parameters e.g. insulations and U-values, the building codes suffer substantial lack of holistic energy efficiency strategies in terms of passive design for cooling and heating. Specifically, some prominent passive design strategies need to be accounted broader within the codes such as solar gains and control, ventilation, and shadings.

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Therefore, at policy level, there has been lack of guidance for the domestic housing industry to explore passive design; consequently passive designs of residential buildings in Iran have not been fully explored.

The published books, journals and researches with relevant subject to passive house have been limited to vernacular architecture, translation, emphasizing on importance of energy efficiency and partial passive design analysis. In some cases, to be explained in next sections, the analyses have been conducted in a way far from the reality of as built or the future construction in Tehran.

Furthermore, an innovative and comprehensive passive design needs to be conducted to address energy reduction in Tehran compatible with the local climate condition, architecture and materials.

3. Methodology

Heavy Passive design in general classified as a) passive heating for cold climate to minimize heat load in building and b) passive cooling for warm climate to minimize cold load [**8**]. For this propose, according to Chan, Riffat et al. (2010) building form and fabric need to be designed in a way that in warmer climate or seasons the heating systems provide or collect and store the solar heat, and retain the heat within the building. In contrast, cooling systems are to provide cold or protect the building from direct solar radiation and improve air ventilation. These strategies of utilising the solar behaviour are known as 'solar passive design' [**8**]. A research in India based on proper design of orientation, structure, envelope and construction materials of a building, the shows that by controlling the thermal loads from the solar heat gain; solar passive designs and double glazing are able to reduce the total heat loss by about 35% [**9**].The passive design including the solar design can be studied over the following categories (figure 2) [**10**]:

- Building envelope (construction materials or fabrics). This refers to walls, windows, slabs, thermal mass and etc.
- Architectural layout design (form). This refers to such aspects of residential architecture as geometry, typology, proportions and shading techniques in relation to energy performance.

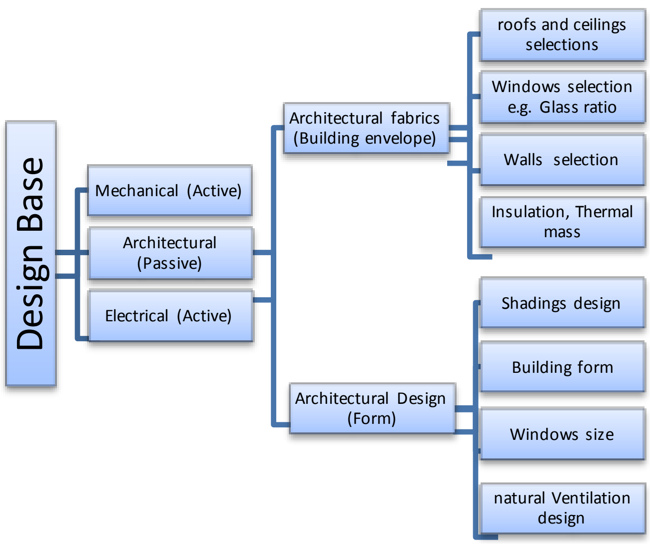

Figure 2, towards passive design

This research will calculate, through the analyzed documents, the energy consumption of classified building in Tehran based on Kwh/m^2. The documents for this purpose are the electrical and gas bills of the each apartment blocks or units. Twelve apartment blocks will be classified to three groups based on their construction practices. The construction practices classified based on (a) light materials, (b) heavy materials and (c) insulated materials. The terms of material, for this study, includes walls selection.

4. Data, Results and discussions

Architectural design and material selection play an important role on energy efficiency in residential units. In a research it was concluded that architectural designs applying energy efficiency strategies reduce energy consumption up to 40-70% [**11**]. Architectural designs mainly focus on achieving energy efficiency without intervention of mechanical equipment [**12**]. In effect, concept of passive design is a relevant method to design an environmental responsive building. Many architectural experts emphasise that the passive design is the best primary approach towards the building energy efficiency, "due to the complexity of designing the energy systems for a high-performance green building, the starting point must be full consideration of passive design" [**13**]. the passive design strategies proves a high amount of energy saving in buildings as well as being cost effective to be implemented [**14**]. The average saving of a passive design building accounts up to 50% of total primary energy[**14**].

Materials with beneficial thermal properties are either insulating materials, or materials with thermal mass and the effect of thermal mass and thermal insulation which are representatives of dynamic and steady state thermo-physical properties of materials must be taken into account simultaneously [**15**].

A list of classified heavy and light materials by their U-value and Y- value in table below demonstrate the classification of materials by their thermal properties (Table 1).

Table 1, Contrasting values of admittance transmittance

Element	*Y-value (W/m^2 K)*	*U-value (W/m^2 K)*
Typical heavy weight materials	4.0	0.6
Typical lightweight materials	1.0	0.6

Wall selection for buildings in Tehran is as shown in table 2. This study has selected three relevant groups of buildings [**15**].

Table 2, Wall material selection for Tehran, Source: Mohammad 2013

Wall reference and type	Construction materials	Detail	U-value (W/m^2 K)	Thickness (cm)	Image of material
HCB1 Hollow clay block	Plaster lining (3 cm) Clay block (15 cm) Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 15 32	1.3	21	
HCB2 Hollow clay block	Plaster lining (3 cm) Clay block [15 cm with 2 cm expanded polystyrene (EPS)] Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 15 32	1.08	21	
L1 LECA block	Plaster lining (3 cm) LECA block (20 cm) Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 20 32	1.34	28	
L2 LECA block	Plaster lining (3 cm) LECA block (10 cm) Cavity filled with expanded polystyrene (EPS) (5 cm) LECA block (10 cm) Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 10 5 10 32	0.41	33	
A1 AAC block	Plaster lining (3 cm) AAC block (20 cm) Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 20 32	0.71	28	
A2 AAC block	Plaster lining (3 cm) AAC block (10 cm) Cavity filled with expanded polystyrene (EPS) (5 cm) AAC block (10 cm) Sand & cement mortar (3 cm) Exterior stone finishing (2 cm)	3 10 5 10 32	0.37	33	

This study has selected three relevant groups of buildings. First group are buildings with light materials which have been detailed in table 3. The total average energy consumption for this group as specified in figure 3 is 283.3 Kwh/m^2 which is higher than the other groups. In addition to the total energy consumption, the gas consumption of this group is the highest rate among the others (Figure 4). However as shown in figure 4, the high energy consumption in this group mainly falls on high gas energy consumption which according to official Iranian source () over 76% of gas consumption belong to required energy for heating in the residential sector.

Table 3, Building descriptions for Light material buildings in Tehran

	Number of Floors - total units	*Total built Area (m^2)*	*Annual Electricity Consumption (Kwh/m^2)*	*Annual Gas Consumption (Kwh/m^2)*	*Total Energy (Kwh/m^2)*
Apartment (A)	5 - 20	1520	41.2	253.6	294.8
Apartment (B)	5 - 15	1110	36.9	213.2	250.1
Apartment (C)	5 - 10	1050	43.3	237.6	280.9
Apartment (D)	5 - 5	620	45.1	261.2	306.3

Table 4 shows the details of second group of apartments with heavy materials, as demonstrated in figures 3 the total average energy consumption of this group is 246.5 Kwh/m^2. These building consumed the lowest electricity among the other groups by 125.3 Kwh/m^2 (Figure 5) which is far less than the insulated buildings and also considerably than the heavy materials group.

Table 4, Building description for heavy materials Buildings in Tehran

	Number of Floors- total units	*Total built Area (m^2)*	*Annual Electricity Consumption (Kwh/m^2)*	*Annual Gas Consumption (Kwh/m^2)*	*Total Energy (Kwh/m^2)*
Apartment (E)	5 - 9	1020	24.1	219.9	244.0
Apartment (F)	4 - 8	560	29.9	227.6	257.7
Apartment (G)	3 - 3	380	21.36	212.4	233.4
Apartment (H)	5 - 10	960	26.6	224.3	250.9

Table 5 shows the details of apartments by insulated materials. The total average energy consumption of this group is 241.5 Kwh/m^2 which is the lowest among the other groups. However, the electricity is the highest source of energy consumption among the other groups.

Table 5, Building description for insulated building materials in Tehran

	Number of Floors- total units	*Total built Area (m^2)*	*Annual Electricity Consumption (Kwh/m^2)*	*Annual Gas Consumption (Kwh/m^2)*	*Total Energy (Kwh/m^2)*
Apartment (I)	5 - 10	1100	40.4	206.9	230.1
Apartment (J)	5 - 15	1280	38.7	191.4	237.1
Apartment (K)	6 - 12	1800	43.5	196.6	240.1
Apartment (L)	6 - 6	1040	41.1	217.8	258.9

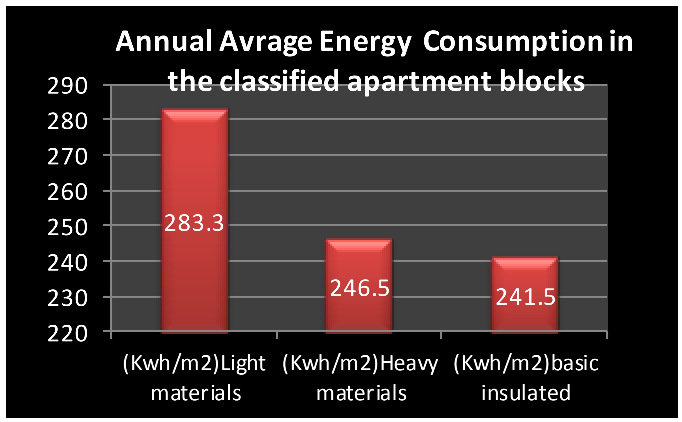

Figure 3, Annual average of gas consumption in apartments

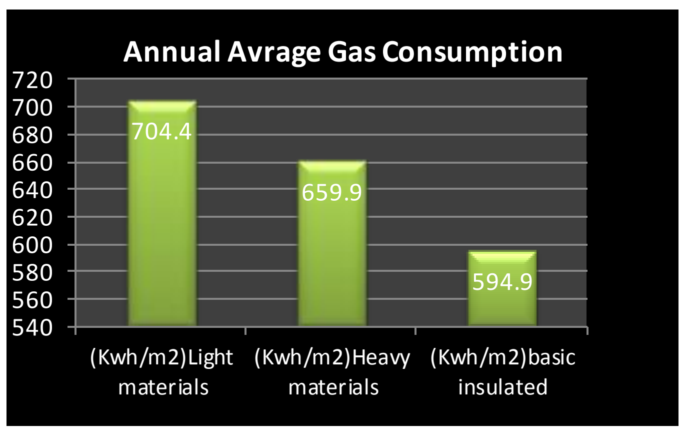

Figure 4, Annual average gas consumption in apartments

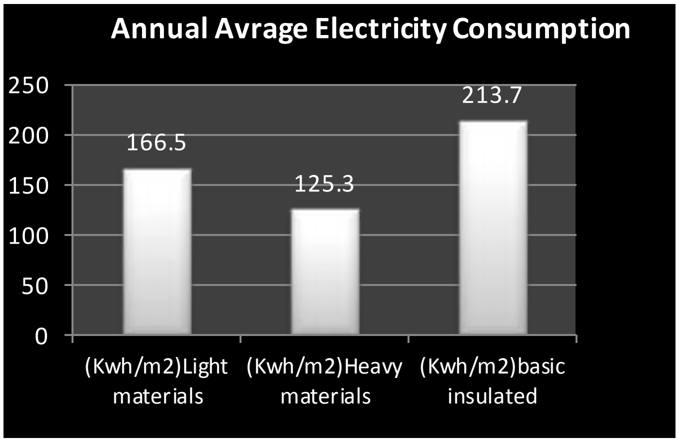

Figure 5, Annual average electricity consumption

5. Conclusions

The collected and analysed data in previous sections suggest that, although apartments by insulated materials consume less energy, further researches, considering all types of materials group and insulation, will be required to contribute to a more comprehensive building material selection for designers and engineers in the future. The finding of this research will contribute to the understanding of building energy behaviour in terms of heating and cooling demand in different seasons of the year. This research also suggests that the current heavy materials and their practices in Tehran is the best practice to reduce the cooling demand. It is worth to mention that, in Iran majority of energy for cooling demand supplied by electricity, and heating demand by gas. However, this research recommend a comprehensive parametric analysis of all building elements and designs to prove the best type of building envelope in this region.

Furthermore, by applying a modelling tool, the most efficient design, as a result of selected elements in the previous section, will be identified and validated by comparison to the baseline measures. By modelling, it will be presumed that efficient selection of elements within proper combinations, will reduce energy consumption, and eventually lead to energy saving in buildings. Therefore, a parametric research will be conducted to model qualified elements. The most efficient combinations will establish energy efficient design strategies in Tehran for designers

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Commonwealth Energy and Sustainable Development Network (CESD-Net)

CESD-Net is a major global initiative in energy and sustainable development. The objective of network is to promote energy and sustainable development in commonwealth countries.

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The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:

Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.

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