Available online at www.elixirpublishers.com (Elixir International Journal)

Sustainable Architecture

Elixir Sustain. Arc. 62 (2013) 17688-17691

ISSN: 2229-712X

Smart systems for manipulation of wall materials of buildings in hot dry zone of Iran

Farshad Kheiri

Architecture and Environmental Design, Iran University of Science and Technology.

ARTICLE INFO

Article history:
Received: 8 July 2013;
Received in revised form:
20 August 2013;
Accepted: 4 September 2013;

Keywords
Sustainable architecture,
Iran hot dry zone,
Traditional architecture,
Thermal concern,
Wall types,
Smart building systems.

ABSTRACT

Environmental concerns have become an important obsession around the world. Architecture plays an important role on the effects of human built environment to the globe. Passive solar energy helps to alleviate the Heating, Ventilation, and Air Conditioning (HVAC) costs and helps to lower the environmental effects. Central and east parts of Iran, called Central Plateau, have hot dry weather. Its traditional architecture propounded some solutions like using thermal inertia of materials to alleviate the severe weather condition of this area. Now, we have more developed industry and different innovations have enhanced buildings materials. In this research, it has been tried to propose a solution for gathering the benefits of traditional and today architecture n hot arid zone of Iran. The proposed system is based on motility of insulation for optimizing the use of thermal inertia and thermal insulation daily and annually. Using smart buildings saves lots of energies and lets the building to respond to its environmental changes like a living creature.

Introduction

Human being is now aware of environmental effects of our built environment [1]. As Human Ecological Footprint has exceeded the Ecological Capacity of Earth in recent decades [2], it seems obvious that all necessary attempts should be carried on at this time. So, in architecture like many other disciplines, sustainability can be the life force solution to have better generation at the time and future.

Building materials are the simplest start point for achieving sustainability in buildings [3, p.7]. Based on Fig. 1, Materials can be considered in three different phases. These phases are pre-building, building, and post building phases [3, p.8].

Building materials are important parameter in buildings construction costs and maintenance. It also affects the environmental situation of indoor spaces. So, it is obvious that it affects Heating, Ventilation, and Air Conditioning (HVAC) systems that consume approximately 54 percent of residential site energy consumption by end use as defined by the U.S. Department of Energy [4, chap. 2, P. 1].

Building sector consumes more than one third of the energy consumed in Iran [5]. So, this is an important matter in this zone like many other areas. Sustainable vernacular architecture of hot dry zones of Iran had answered to choosing the sustainable materials in its traditional constructions. But, today we have faced problems which were not in previous times. Increasing population in cities because of migrations from rural areas to cities, improved health care and other similar affairs, industrialization, transportation, environmental concerns, and many other problems propounds a different style of living for today. So, it is useful to use the basic rules in traditional architecture and implement it with today necessities and technologies.

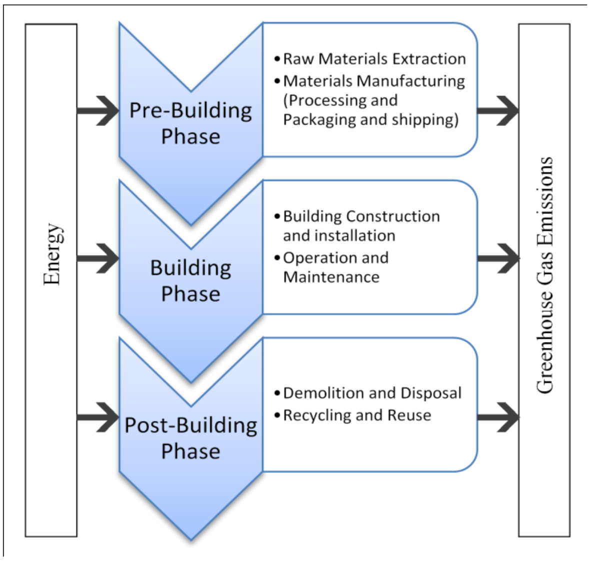

Figure 1: Different Phases of the Building Material Life-Cycle

Environmental Situation of Hot Dry Zone of Iran

Hot dry climate of Iran creates a large portion of this country and mostly is referred as Central Plateau. The central part of it, called Central Plateau is placed in central latitude of 32° 25' N and longitude of 53° 24' E, and has 432,084 km^2 (166,828 mi^2) area [6]. The weather is very warm in summers as the highest temperature reported by satellites is from “Gandom Beryan Hill” embodied in this area [7]. As a desert like climate, it has warm summer and cold winters. The other specification of this place is the low level of precipitation in this area. It is also worthwhile to mention to the considerable difference between days and nights temperature.

Tele: +98-131 7274177
E-mail addresses: far.kheiry@gmail.com

Materials Used in Traditional Architecture of Iran in Hot Dry Zones

1. Pre-Building Phase of Traditional Architecture

Soil is the prevalent substance covered a huge amount of the aforementioned surface. In this area, stone and wood would be found scarcely and sometimes seldom. Therefore, the construction techniques of traditional architecture had been focused on materials built from soil. Consequently, different kinds of bricks and probes with different kinds of mortars compatible for diverse situations were mostly used.

Mostly, materials for constructions were used from the construction site. This means that raw materials transportation was eliminated from energy consumption. Digging the site and constructing the building in lower level would also help to use earth thermal inertia, use earth as the buttress of roof vaults, and access to underwater sources.

Processing was mostly with lowest energy. Although some finishing like tiles had to consume more energy for processing, the total and common ones were simple and caused those construction materials to be perceived as low energy embodied.

2. Building Phase of Traditional Architecture

In building and maintenance phase of a building, energy resources for HVAC systems are important. For lowering these consumptions, some features of building elements play important roles. Heat capacity of the exterior skin is one of these items. Heat capacity is the amount of heat required to raise the temperature of a given mass of a substance by one degree Celsius. Thermal capacity (or heat capacity) of a wall is related to its mass (or density, thickness, width, and height that can show the mass), and specific heat capacity. If the thermal capacity of an object is bigger than other one, it means that it takes more time for it to transfer the heat from one side to the other one. This delay is called time lag [8]. The time lag of some of the used materials with different thicknesses in walls has been depicted in Table 1.

As noted in Table 1, a 30 cm brick wall used in many traditional buildings would cause 8.5 hours delay for transforming the heat. Therefore, when the exterior facet of the wall (specially south, south west, and west walls) reaches to its highest temperature in the afternoon, it takes 8.5 hours to transfer it to the interior facet when it has become night and that can be useful to become heater. The specified flow slows down as the inside and outside temperature become closer to each other and would change direction when in some seasons the outside temperature becomes lower than inside at night.

The mentioned process is not the same as in cold seasons in winters. As the inside temperature of a room is higher than outside one during day and night, the thermal flow becomes one directional from inside to outside.

The process of fabrication was affordable for people who were aware of the modules of buildings (as all of the constructions had mostly two modules; the small module was 93 cm and the large module was 120 cm) [9]. Renovations also were completely easy as the materials were available around the constructed site.

3. Post-Building Phase of Traditional Architecture

Although brick has been manufactured and would bring back to nature in a long period of time, but it can be reused in some circumstances. Wood is theoretically renewable. Hard wood takes about 80 years to grow up. It can be reused in the form of lumber, and recycled in the form of strand board. It also would go back to nature easily. Glass can be reused easily if it is dismantled and is not mixed with other demolished materials. It can be recycled with heat [3]. Also, some glasses above doors were used from broken particles of previous windows [9].

Table 1: Materials Conduction Specifications [8]

Material	Thickness (cm)	Conduction Coefficient (BTU/h/ft^2)	Time Lag (hour)
Stone	20	0.67	5.5
	30	0.55	8.0
	40	0.47	10.5
	60	0.36	15.5
Concrete	5	0.98	1.1
	10	0.84	2.5
	15	0.74	3.8
	20	0.66	5.1
	30	0.54	7.8
	40	0.46	10.2
Brick	10	0.60	2.3
	20	0.41	5.5
	30	0.31	8.5
	40	0.25	12.0
Wood	1.25	0.68	0.17
	2.5	0.48	.045
	5	0.30	1.2

Mentioning this point is important that the use of a building in previous centuries were longer than buildings today. The durability of them, compatible with the smooth style life of that time, was a benefit and caused great energy efficiency. Aesthetically also, the composition of built environment and their natural context had appreciable harmony.

Materials Used in Contemporary Architecture of Iran in Hot Dry Zones

Material science has had great achievements during recent century. We now have the ability to manufacture raw materials to a high quality one in bearing loads, thermal concerns, and acoustics as instances. As an example, Aerogels which has been invented based on nanotechnology, offer 2-3 times the insulating value of other common insulating materials and also High-insulating Nanogel panels are available with up to 75 percent translucency [10] (Fig 1). We now have steels tougher, concrete better treated, glass self cleaning, and insulation plasters based on nanotechnology science too [11]. We have standardized required quality for different functions. The invention of different tools like CAAD Software help to calculate mechanical and physical characteristics of buildings and have estimation of costs beforehand.

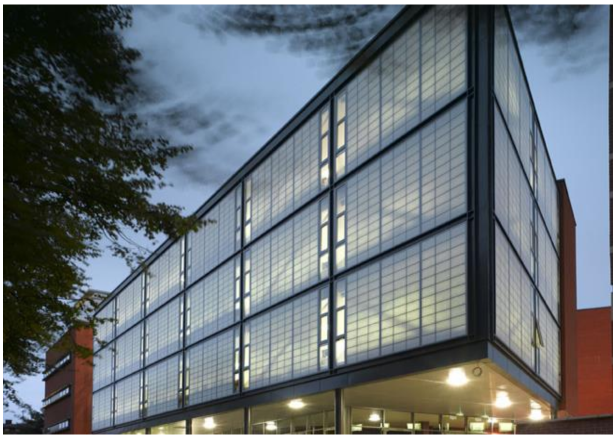

Figure 2. Kallwall Wall Cladding [12]

Wall systems have been changed consequently. Diverse systems [13] for different conditions and functions would propound good solution in many cases, but they have their own deficiencies. A set of prevalent wall types in Iran is described in Table 2.

Table 2. Prevalent Wall Systems in Iran

Wall Type	Advantages	Disadvantages
Clay Block - Cement and Concrete Blocks	• Durability • Reusable if it has tongue and groove joint • Insulating if a sheet of polystyrene or similar insulations are implemented inside it • Nontoxic • Acceptable embodied energy • Natural material • Fire resistant • Local raw material	• Difficulty in recycling when demolished materials are mixed • Low thermal and acoustic features when it is not reinforced with insulations. • Pollution
Gypsum Block	• Reusable • Nontoxic • Natural material • Fire resistance • Speed of fabrication • Light weight	• Fragility, mostly in joints • Vulnerable when it is in touch with water • Causing erosion when it is in touch with steel
Sandwich Panel	• Recycling • Reusable • Light weight • Speed of fabrication • insulated	• Usable for industrial buildings • If polyurethane is used as the core material it is toxic. Also, the glue between metal sheets and core can be toxic
3d Panels	• Stability of panels as a unique system • Ease of transportation • Speed of fabrication • Ease of fabrication • Insulated • Acceptable infiltration	• Lack of flexibility in height • Heavy weight • Not reusable and quite difficult to be recycled • Restrictions in openings • Restrictions in renovations and access to mechanical and electrical equipments. • Water and other materials waste • Difficulties for low thermal inertia in areas with drastic daily and annual temperature
Dry Wall	• Speed of fabrication • Ease of fabrication • Light weight • Fire resistant • Ease of renovation • Reusability • Recycling • Ease of access to mechanical and electrical equipments • Ease of transportation	• Low mechanical durability (specially for concentrated pressures) • Vulnerable when it is in touch with water
Insulating Concrete Forms	• Durability • Ease of transport • Acoustic and thermal insulation • Nontoxic	• High embodied-energy (at final phase) • Large amount of waste water

Discussion

As described above, in traditional architecture, thermal comfort was greatly based on thermal inertia of construction to moderate diverse daily changes in temperature. In some cases, mostly in roofs (domes in hot dry zones and flat in cold mountainous zones), we see a gap of air between two construction. So, this insulation was mostly restricted to roofs as the most effective element in one or two flat buildings thermal concerns [8].

Today, apartments have been the prevalent construction of most of the cities. On the other hand, walls (except some structural walls like shear ones) do not bear loads; so they are not considered structurally. On the other hand, concerns about weight have been an important feature in buildings. As the result, the materials used in walls are more based on having insulation features rather than thermal inertia. HVAC systems also play important role in this case.

The other thing that is based on the speed needed for construction and also industrial features is that mostly all sides of the buildings are considered the same. But it is clear that each side has its own potential and should have its own characteristics. For example, east and west sides of a building in hot dry zone gain a lot of solar energy. So, thermal inertia is very important in these cases. Theoretically, east walls should have materials those cause a time lag about 12 to 17 hours. This is not practical, so it is better to reduce it to approximately zero. This means as the temperature is low in the morning, the heat that has been absorbed by these walls should be transferred in inside without any delay. West walls should have 5 to 10 hours delay and south walls, as they gain less solar rays in hot seasons that east and west ones, can have 7 to 10 hour time lag. Among all sides, north one has the least importance in case of thermal inertia, but a 5 to 10 hours time lag helps to achieve comfort for occupants [8].

When we consider the weather situation of hot dry zone of Iran with drastic daily and annual changes, we will reach to the point that the best situation for lowering environmental effects and costs of HVAC systems is to have flexible smart buildings (at least smart skins of the buildings). We have had seen different kinds of motile structures for different reasons. Many of these flexible structures are for passive energy concerns and lead to have more sustainable building [14-21]. These are to design a construction which is more responsible to their milieu and therefore they are more compatible with sustainable rules.

In hot dry zone of Iran, we can separate two kinds of weathers during the year; approximately moderate and severe one. In moderate one, thermal inertia is more important for the comfort of occupants. In severe seasons, thermal resistance is more important. Therefore, if we have controlled insulation that can be fixed and dismantled, we can use thermal inertia in moderate weather and insulation in severe ones. This also can be applicable during a day when temperature changes drastically. One of the attempts on this feature is done on insulation of windows with polystyrene that can be blown to the space between two glasses of a double glazed window and can be removed from the space between two glasses whenever needed [22].

With the implementation of smart systems which are able to monitor the internal and external weather situation and process to find the best solution, we can have buildings with benefits of both traditional and today techniques.

Conclusion

Thermal considerations are important features in occupants' comfort in a building. Different systems can cause drastic changes in HVAC costs and therefore they would have large environmental effects. Using passive energy is a way to design energy efficient buildings with the use of renewable and clean energy sources.

Hot dry zone of Iran has severe weather condition in summer and winter. With using thermal inertia of walls, the weather of spring and fall could be brought to the comfort zone. Insulation is a better solution in severe conditions. Therefore, here it has been proposed to have a flexible insulation in walls and windows. The mass of walls would be designed based on their thermal inertia, geographical direction, and constructional features.

It is obvious that the best implementation of this system in any microclimate needs its own investigations and researches.

References

[1]. Rosse, W. Nicholas, 2011, “A National Sustainable Building Strategy: Planting Seeds of Human Ingenuity in the Built Environment”, Available at SSRN: http://ssrn.com/abstract=1740026 or http://dx.doi.org/10.2139/ssrn.1740026

[2]. Borucke, Michael, David Moore, Gemma Cranston, Kyle Gracey, Katsunori Iha, Joy Larson, Elias Lazarus, Juan Carlos Morales, Mathis Wackernagel, Alessandro Galli, 2013, “Accounting for demand and supply of the biosphere’s regenerative capacity: The National Footprint Accounts’ underlying methodology and framework”, Ecological Indicators 24, 518–533, Elsevier Ltd.

[3]. Kim, Jong-Jin, Brenda Rigdon, “Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials”, National Polution Prevention Center for Higher Education, 1998, 1-44.

[4]. “2011 Building Energy Data Book”, Prepared for the Buildings Technologies Program, Energy Efficiency and Renewable Energy, U.S. Department of Energy, by D&R International, Ltd, 2012.

[5]. National Building Regulations, 19th sector, Ministry of Housing and Urban Development, Iran, Tehran, 2002.

[6]. Retrieved on April 12, 2013 from website http://www.peakbagger.com/range.aspx?rid=432

[7]. Retrieved on June 2, 2013 from website http://news.discovery.com/earth/global-warming/hottest-spot-on-earth-120416.htm

[8]. Kasmai, Morteza, “Climate & Architecture”, 4nd ed., 2006, pp. 107-130.

[9]. Pirnia, Mohammad Karim, Stylistic of Iranian Architecturem, 3rd ed., 1383, pp. 32.

[10]. Elvin. George, Nanotechnology for Green Building, Green Technology Forum, 2007, p. 15.

[11]. Thakur, V., D. Mandloi, "A Prudent Approach to Civil Engineering: Nano Materials", Journal of Environmental Science, Computer Science and Engineering & Technology, 1 (3): 263-270.

[12]. Retrieved on June 02, 2013 from website http://jacobsens.co.nz/commercial/cladding/kalwall/

[13]. Retrieved on May 21, 2013 from website http://ravesh-ejra.mihanblog.com/extrapage/divar

[14]. Asefi, Maziar, 2012. "The Creation of Sustainable Architecture by Use of Transformable Intelligent Building Skin", International Journal of Civil and Environmental Engineering, 6: 329-332

[15]. Atkin, B., 1998. “Intelligent Buildings: Applications of IT and Building Automation to High Technology Construction Projects. Kogan.

[16]. Fox, M.A., 2003. “Kinetic Architectural Systems Design”, IN Kronenburg, R., Lim, J. & Chii, W. Y. (Eds.) Transportable Environment 2, London, Spon Press, 112-128.

[17]. Asefi, M., 2010. “Transformable Architectural Structures: Design, Evaluation and Application to Kinetic Architecture”, VDM Publisher, Berlin

[18]. Ghamari, H., M. Asefi, 2010. “Toward Sustainability by the Application of Intelligence Building Systems”, the Second International Conference on Sustainable Architecture and Urban Development, Amman, Jordan, SAUD 2010

[19]. Magnoli, C., L. Bonann, R. Khalaf, 2001. “Designing a DNA for Responsive Architecture: A new Built Environment for Social Sustainability”, IN Brebbia, C. A., Sucharov, L. J. & Pascolo, P. (Eds.) Comparing Design in nature with Science and Engineering, London, Computational Mechanics, 56-62.

[20]. Sherbini, Kh., R. Krawcyk, 2004. “Overview of Intelligent Architecture”.1st ASCAAD International Conference. E-Design in Architecture KFUPM, Dhahran, Saudi Arabia

[21]. Wigginton, M., 2002. “Intelligent Skins. Butterworth-Heinemann Linacre House”, Jordan Hill. Oxford.

[22]. Alambeigi, Pantea, 2013. "The model of designing solar wall for optimizing the use of daylight and energy focused on movable design in an office building", Journa of American Science, 9(5): 104-114.