ABSTRACT

Development of scientific system and relevant technology requires tools; hence, planning, adjustability and variability need to be along with a system which not only coordinates elements and factors influencing on design and implementation but also is efficiently and easily run. According to great investments on housing and related industries, this is particularly important in design and construction a building. Iranian architecture has been consistently focused on positive architectural aspects such as logic; stability basics; technical and scientific principles of the structure; human scale; application of local materials; savings and light weight construction etc. Light-weight construction is a process which can be applied at the start to the end of the construction. What is known as light-weight construction in modern days is a discussion which was focused on in the past; and the current generation possessing the fruit of centuries experience and innovation as the initial capital need to best use this great heritage. Hence, the present study attempts to examine, describe and define light-weight construction; identify its effects and applications; followed by analyze these concepts in Iranian architecture in order to achieve a logical objective strategy for designing structures by light-weight construction technologies.

Key words: Iranian architecture; light-weight construction; technology

Introduction

In modern era as population, needs and necessity of adopting new methods and materials increase in order to accelerate construction, light-weight technology, increased lifetime and earthquake resistance became more important than past. Decreases in finished building weight using construction techniques, new materials and optimized implementing methods not only save cost, time and energy but also decrease damages resulted from natural disasters such as earthquake minimizing damages of high weight structures [1]. This is possible by taking advantage of experiences consistent with geometry and symmetries related to science and the skillful architecture. In Iranian architecture, nothing is exclusively performed to decorate. Instead, all are done necessarily and suitably in elegant and eye-catching ways and they are decoratively exhibited. Meanwhile, Iranian architects and engineers have interested in a discussion of light-weight construction and decrease in dead load of the structure which make the building resist against potential tensions and light weight elements. Present study defines light-weight construction and describes related effective factors; then introduces relevant existing technologies and finally compares light-weight construction methods in Iranian architecture.

2. Definition of light-weight construction and related consideration:

Light-weight construction is a process which can be applied at the start to the end of the construction. The process is performed by two main methods as follows:

- Lightening carrier elements of structure
- Lightening non-carrier elements of structure

Two factors, material weight and their enforcement techniques, play a determining role. Both factors are clearly considerable in Iranian old architecture based on time conditions, construction technology and available materials. Obviously, a structure is consists of different parts. Some are carrier or structural and the other are non-carrier or non-structural. Materials used in these parts certainly possess different characteristics. Establishment of constructing blocks and spatial form of the structure are effectively determining factors on its weight followed by considering internal design of spaces, wall kinds, flooring details, front, opening levels and internal partitioning which are describe below:
2.1. Effect of locating internal spaces in the structure:

The length of internal partition walls are most influenced by changes in internal architectural plan. Nature of the effect is greatly depended on building type, aggregate design of service spaces, implementing basics of national construction regulations and meeting requirements of design in order to optimize spaces and decrease solitary spaces. This is achieved by modification and creation of a flexible design process in providing internal architectural plan.

2.2. Effect of front design:

Designing the front of a building three factors should be considered:

2.2.1 Materials and thickness:

Considering that the front is exposed to harsh atmospheric factors, adopting materials should be cautiously done based on climate and environmental conditions in order to increase resistance against them and preserve the beauty of the structure while material weight used in the front does not increase. Mixed fronts (20% stone and 80% cement) in apartments or metal, aluminum … fronts are examples of such structures.

2.2.2. The wall behind front:

Light-weight walls (for example, HEBLEX) by 10 cm in thickness play an important role on decrease in total weight of walls behind the front in order to light-weight construction and provide more space by meeting the following requirements:

2.2.3. Window level:

Buildings with non-carrier wall systems provide more options for designer to determine window levels; thus, the designer can determine window level based on light requirements. Obviously, percentage of window level to wall level ratio is a standard in calculating total weight of front. Naturally, as window level to wall level ratio increases, total weight of structure walls decreases. Optimal condition of window level to wall level ratio is determined by considering effect of window size, glass size and window opening sizes on economic analysis in proportion to implementing wall.

2.3. Effect of external walls:

Total weight of external walls depends on material type used in the wall, length, height and thickness of the wall. Wall height is a function of floor height and ceiling thickness. Wall length is a function of geometric design of plan which was examined separately.

3. Materials and technologies of light-weight construction:

In modern world, new materials used in construction meet the limitation of wall thickness in order to decrease wall heat transfer in addition to contribute to lighten walls; thus where possible light resistant materials must be used for construction. In following, examples of light-weight materials and their effects on light-weight construction are architecturally summarized.

3.1. Gas light concrete blocks and panels:

- This concrete material is provided as large prefabricated blocks and parts for ceiling, floor and wall [2].

3.2. Granular light concrete blocks and panels:

These blocks are produced as 15, 20 and 25 cm in thickness. Granular light concrete blocks are produced as filled and hollow forms installed in wall, floor and ceiling.

3.3. Perlite as a local material to lighten concrete:

- Expanded perlite is extensively used in construction and other industries due to its low apparent weight as well as low heat coefficient and high sound absorption. Perlite particles combine with Portland cement and water and produce a light concrete which can be used for filler walls, light ceiling, main ceiling coverage, prefabricated productions and various insulated examples [9].

3.4. Dried cement panels as new light-weight materials used for covering internal and external walls:

Dried cement panels can be used for any kind of construction including internal wall coverings exposed to water and humidity; external front covering; various ceiling and floor coverings; various commercial, industrial, agriculture building and finally as available materials for people. There are many benefits for the system compared to heavy materials the most important of which are that they are waterproof and humidity resistant. The system is produced and used in different size and thickness, needed architectural shapes, various colors and fire resistant. This accelerates construction due to its driedness; various fronts, decorations, tiles, ceramics etc … can be implemented on the system. This dried structure is suitable for implementing internal walls
in high humid areas; it is used to complete external walls, front and floors as well. According to above, dried cement panels are suitably established substitutes for internal and external walls made of brick, blocks and totally traditional materials. The most important advantage is light weight which results in decrease in dead weight of the structure and earthquake related consequences. The weight of 1 m² wall made of Gary bricks, cement and sand mortar by 10 cm in thickness, a layer of plaster, soil and whitewashing in one side is almost 300 kg. if the same wall is implemented by light clay brick, it weighs almost 150 kg/ 1 m². Whereas 1 m² made by single layer system weighs only 30 kg/ 1 m². This comparison shows that dried system weighs 10 to 5 times less than traditional systems. There are other advantages including nonflammability; fire resistance; prevention of sound, heat and cool transfer from an area to another; simple maintenance; water and moisture resistance; simple installation; more strength and durability; and finally economically application in construction industry which guarantee the system superior [2].

3.5. Self dense concrete in light-weight construction:

Self dense concrete can be used for light-weight construction which is considered a new industry in Iran [7].

3.6. False ceiling and composite fronts:

False ceilings and composite fronts are highly used in internal decoration of the building due to their light-weight qualities.

3.7. Wooden partitions:

Wooden partitions are examples of elements partitioning various architectural spaces. These partitions are light, low volume and stylish.

4. Light-weight construction as a protective basic in Iranian architecture:

Light-weight construction has been not only important in Iranian architectural construction but also it was used in maintenance of the architecture as far as a productive method existed in traditional building maintenance system called ‘light-weight construction’. Light-weight construction means removal of moisture insulated layers and reaching to main structure; because totally in traditional buildings, especially in mud architecture of center Iran, roofs were annually or biennially insulated by a layer of mud plaster earlier in rain-fall season; gradually a layer formed with more than 1 m in diameter on the roof which considerable weight could be attributed to; this layer overloaded the structure. Thus, lightening roofs was performed every few years. As heavy mud mortal layers were removed, the roof reached its initial weight and the structure experienced suitable conditions [10].

5. evaluating examples and methods of light-weight construction in Iranian building architectures:

Remains of Iranian architectural buildings possess a great knowledge that can be used to solve problems raised in Iran.

Light-weight construction has been consistently considered in relation to carrier walls and columns, as well as ceilings (vertical elements) and building coverings (horizontal elements) to other non-carrier elements which are described in the following. Lightening has been performed by three main methods:

1. Decrease in cross section
2. Decrease in material weights
3. Using light-weight construction techniques

5.1. decrease in cross section:

A most common strategy to decrease structure average weight was decrease in cross section as the structure height increases (Figure 1). Since the traditional structure mass generally tolerated pressure force and it was managed by transferring pressure forces, as height increased, consumed material mass lowered by decrease in cross-section of carrier member so that the structure did not tolerate doubled pressure force which is material weight. Decrease in cross-section is met in vertical carrier elements as well as curve carrier arcs and domes so that as height increases, the thickness gradually decreases from leg to the tip.

5.2. Lightening by decrease in material weight:

Old lightening techniques used by architectures and engineers are the realization of weight pyramid by decrease in consumed materials as height increases. This is done by four main methods as follows:

1. Decrease in material sizes
2. Decrease in architecture weight by changes in material (using lighter materials)
3. Decrease in material density and using less dense materials.

In the following, these methods are described.

5.2.1. Decrease in cross-sectional sizes:

Decrease in material sizes has been a common strategy for traditional light-weight construction. The sizes of brick used in lower parts of the building were different from same materials used in higher
parts. Naturally as material sizes decrease, total weight of the building decreases [2].

Fig. 1: decrease in cross-section and light-weight construction in higher parts by various methods in historical building elements

5.2.2. decrease in structure weight by changes in materials:

Changes in materials and using lighter ones in higher parts is a common strategy to realize weight pyramid law [6] so that changes in materials of walls and roofs are visible. In large parts of Iran, a common practice was forming baked natural soil and in more advanced form, as baked bricks. The brick which is considered as heavy materials is the main material in Islamic Iranian architecture. Pressure resistance of brick is used for constructing carrier wall of dome and are.

The changes in materials can be generally classified as follows:
- Stone wall and brick ceiling
- Bricked wall and bricked ceiling
- Bricked wall, wooden ceiling or herbal derivatives such as mat

In most Iranian old architectural buildings especially in areas where wood, straw and mat is abundantly found, walls are made of masonry materials and ceiling is covered with slabs, beams or mats, straws and such light materials. In these buildings, low-weight ceiling, compared to walls, increases resistance of the building against potential tensions [10].

5.2.3. Decrease in material density:

In traditional buildings, materials with similar appearance and sizes are not necessarily equivalent in weight. Two bricks with similar sizes can be different in terms of weight depending on raw materials (soil) or brick baking amount. Material density followed by material weight were controlled when producing bricks by taking advantage of various soils found in the region or neighborhood with different density and aggregation characteristics. Rabbit ligaments of Nodooshan is a good example that architect produces 2 types of brick using the soil taken from two region; these bricks are considerably light. Lighter brick is used in higher parts and stone brick is used in lower carrier parts. For stone or wooden structures materials with different weights has been used. In this method, material appearances are almost similar but their weights are completely different.

6. using light-weight construction techniques:

The architects used various methods and techniques for light-weight construction. The most important and common methods are describes as follows. It is worth noting that these methods not only lightened the structure but also had other applications. In the present study, the former is considered.

6.1. cavity walls:

Lightening in the past architecture was not limited to carrier elements; instead, non-carrier elements were lightened too including non-carrier walls which generally played a partitioning and separating role; for example, cavity wall was considered as a strategy to build fences and shelters. In this practice, bricks were arranged so that minimum bricks formed largest part of the wall; they were generally used in edge of the garden walls, roof shelters and higher parts of the portioning non-carrier walls. So, a hollow was created among bricks; every few bricks (3 or 4) formed a cube-like shape called cavity. The method was practiced by different details; as the consumed materials decreased the structure weight decreased.
6.6. domes:

Although in traditional Iranian architecture the mass of columns and carrier walls tolerated load and these elements needed to be designed and constructed solid. While in many situations, methods were used to minimize these element masses by technical provisions in order to discharge some parts. Concavities are considered as important factors for decrease in dead load of the structure. Significant weight and volume is assigned to pillars and columns by structural requirements. Openings, niches and shelves installed in these great pillars are considered as important strategies. This is practiced in carrier walls by meeting standards of structural strength and especially in non-carrier walls. Besides, these spaces are functionally used in Iranian life style.

6.5. pollinates in curved arches:

Convex forms interface creates concave bodies which make it difficult to use its surface. The architect converts this structural form (convex) to needed form in external surfaces (flat surface).

6.4. networks in flat arches:

Flat arches including sloped ones were common generally in areas where wood was abundantly found.

6.3. networks:

Networks considerably decrease structural weight by reducing consumed materials. This would decrease about half of the material weight. In Iranian architecture, walls and even lattice canopies are especially implemented. Using networks was common to reduce non-carrier wall weights as well as in roof shelters.

6.2. niches, concavities and hollow columns:

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6.0. introduction:

In traditional Iranian architecture, structural weight was properly reduced using network forms. It was common to reduce non-carrier wall weights as well as in roof shelters. The use of networks was common to reduce non-carrier wall weights as well as in roof shelters. Significant weight and volume is assigned to pillars and columns by structural requirements. Openings, niches and shelves installed in these great pillars are considered as important strategies. This is practiced in carrier walls by meeting standards of structural strength and especially in non-carrier walls. Besides, these spaces are functionally used in Iranian life style.

7. conclusion:

Architecture is a mix of science and art, belief and faith, and special skills along with civilization, culture and history as expressive language of its time. Technology is a civilizing tool. Islamic civilization was able to lead large parts of the world for centuries and it reveals that such a civilization was essentially established on important technological achievements. Iran is full of experiences and examples which are evidence of old knowledge about construction. In the past, light-weight construction was important for Iranians; they provided thoughtful strategies according to the technology of the time. Scholars used mathematics and geometry for architecture; they knew forces and realized their movements in creating cavity domes. Centerpiece covered arches are suitable for lightening as well as balancing indoor and outdoor temperature. Lightening walls and pillars by constructing niches in Jabalie Dome of Kerman attributed to early Islamic period. This dome had been constructed on an octagon. The walls were lightened by many niches and this is the most important characteristic of the structure.

There was a large mass in walls due to usage of heavy materials. Architects in the past, reduced wall mass by covering arches, discharging pillars as a niche, repeating arches and discharging inside the walls with successive arches. Niches in wall fronts simultaneously decorate and contribute lightening the structure (Moshtagh Alishah Temple in Kerman, Agha Bozorg School in Kashan). The domestic architecture is full of experiences and examples which are evidence of old knowledge about construction. In the past, light-weight construction was important for Iranians; they provided thoughtful strategies according to the technology of the time. Scholars used mathematics and geometry for architecture; they knew forces and realized their movements in creating cavity domes. Centerpiece covered arches are suitable for lightening as well as balancing indoor and outdoor temperature. Lightening walls and pillars by constructing niches in Jabalie Dome of Kerman attributed to early Islamic period. This dome had been constructed on an octagon. The walls were lightened by many niches and this is the most important characteristic of the structure.
important and effective steps toward achieving goals in future can be passed and light structures can be developed.

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