American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

# Light Weight Steel Frames vs. Common Building Structures - Structural Performance Evaluation

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**Abstract**

In the event of an earthquake, one of the efficient methods is to use Light Weight Steel (LSF) systems. In this regard, light weight and numerous load bearing members can reduce level of input earthquake energy to the structure. In modern societies which speed and productivity in every context is deterministic, application of rapid and optimal methods such as LSF systems in the construction industry seems inevitable. In other words, for the sake of strengthening structures against earthquake, various methods have been used. Due to seismicity of the region in which Iran is located and high seismic hazard, it must be attempted to lead performance of structures toward least life and financial losses .One of the novel and applicable methods for improving seismic behavior of structures is to use LSF. Principle of work of structures implemented with LSF system is based on the number of load bearing members which leads to compensation of the weakness of a member by other members in case one member fails as a result of weakness or any other reasons. Some benefits of such structures are: light weight, easy transportation, rapid implementation and suitable resistance against earthquake, reduction in energy costs and acoustic isolation. In this paper, Light weight steel frames vs. common building structures - structural performance were evaluated.

***Keywords:*** Light steel frame (LSF); Structural performance; Building industrialization; Strengthening.

## 1. Introduction

In common buildings in Iran, despite of modern design, implementation of structures is weakly performed. It means that actual behavior of structure is completely different in service from what is designed for. Therefore, close monitoring of the quality of implementation and compliance with calculated details is a mandatory issue. For this reason, prefabricated buildings show suitable behavior of a structure in servicing since they are fabricated in factory and went through quality control and manufacturing stages in accordance with as-built and calculated drawings.

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In this regard, light steel frames (LSF) are having the great advantage over the other structures due to the benefit of higher factory production quality and more simple, more reliable, much more consolidated and rapid connections system.

Strengthen the structures is one of the most efficient methods to prevent unwanted happenings as well as life and financial losses which came out of the natural disasters such as earthquake and storms is to. However, today the importance of this matter must be considered more so before constructing a structure, with a long term vision, strengthening can be embedded within the system of structure construction to eliminate the need for improvement of constructed structures in its future. Light steel frames can reduce the effect of lateral forces of earthquake through the concept of lightening of structure. This matter, illustrates the fact that strengthening is not the first and the only solution for solving the problems, but the concept of lightening the structures can help up in strengthening to a great extent. These frames, which are utilized in this system, are composed of light galvanized plates. Light galvanized plates have other benefits beside aforesaid benefits which are explained in what follows. In case of an event, LSFs can considerably reduce the effect of applied loads. Besides, after event, such structures can be used as an alternative for damaged structures. These structures can be erected within 2-3 days and as a result, being aware of the technology of construction of them can solve many of the problems including lack of time [1].

Owing to various benefits such as high speed , high quality of fabrication beside the construction and seismic performance suitability in recent years, application of LSF system has grown significantly all around the world. LSF system is comprised of steel members with CSF section entered construction industry since 1964. However, their usage became limited as a result of economic considerations. After 1990, for various reasons such as increase in wood price and limited resources for it, environmental problems, demands for rapid and massive construction as well as necessity of using prefabrication structures, LSF systems found extensive usage so that today, this system is extensively used for construction of commercial and residential buildings with low and moderate-rise in US, Canada, Australia and Japan and many other countries [2].

In this paper, we intend to provide a comprehensive understanding about LSF structural systems in the field of design of such structures and explain some of the benefits and superiority of these structures compared to common structures which are built in Iran. Furthermore, performance of these structures against earthquake will be described by referring to literature.

## 2. Characteristics of structures implemented with LSF system

### *2.1. Details of LSF structures*

LSF structures are fabricated in the form of panel and each panel is composed of following members:

1. Vertical load bearing members
2. Frame connecting members
3. Roof bending members
4. Lateral load bearing members

Moreover, connections of this system are in the form of bolts as well as $CO_2$ welds in factory conditions [3].

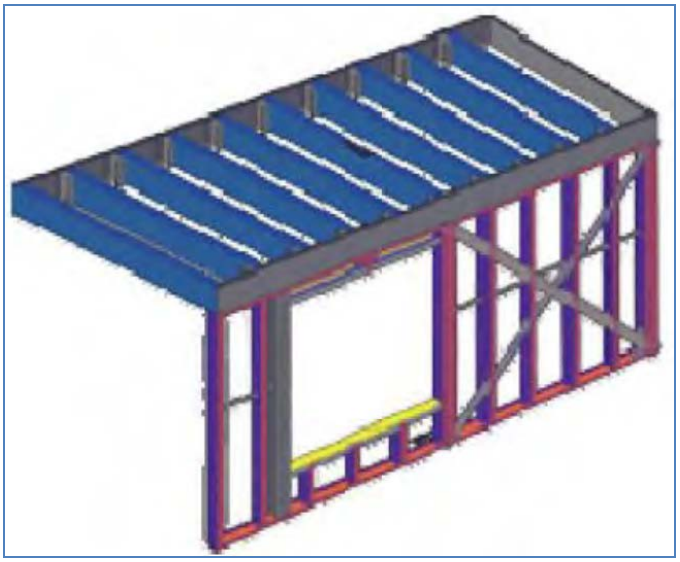

**Figure 1:** One of the members of LSF system [3]

### 3. Design of LSF structures

To appropriately design LSFs, it is important to model the structure in three dimensions and with high accuracy. In this paper, design is performed by using Frame Builder exclusive software of Genesis Company which is one of the most advanced software for design of structures having outstanding characteristics of professional design together with presenting executive details for all sorts of buildings. Aforesaid software provides executives, customers and beneficiaries with all required information, drawings and procedures to improve implementation operation for buildings as well as suitable economic saving achieved by using light steel frames.

After making 3D model of the intended building, appropriate framing would be assigned based on engineering principles and computations. Then, drawings which are corresponding to manufacturing and installation of panels would be prepared. The issued drawings should take into account all engineering details and considerations in a specific manner.

Drawings are divided to following groups:

1. Drawing of walls, roofs and corresponding connections including size of structural members, thickness of plates, distance of members, location of load bearing and non-load bearing walls, details of connections and considerations of regulation.
2. Drawings of roof and trusses (if necessary) and relevant connections which are including trusses production drawings, braces of roofs, connections and regulation implications.

### *3.1. How to define in ETABS and SAP*

Since in ETABS and SAP it is not possible to define some double sections used in LSF and there is no option to define actual geometric specifications based on cold rolling, to accurately define used materials, some secondary software such as CFS software is utilised to define intended sections and reduced geometric specifications extracted by taking into account specifications of cold rolled sections as well as buckling length considerations and so on which are presented in AISI regulations for such sections which must be used.

After extraction of geometric specifications from software, one can define intended section in ETABS and SAP according to extracted specifications in general form. Then, structure can be modeled in three dimensions as steel structure and designed as ASD or LRFD [3].

## 4. Benefits of LSF system

This system has various benefits and some of them are described separately here:

*From customers' point of view:*

1. High safety against fire and earthquake
2. Low maintenance costs
3. Long lifetime
4. Absence of cracks available in joint surfaces

*From investors' point of view:*

1. High quality
2. High implementation speed
3. Rapid investment return
4. Being more economical compared to other common systems
5. More added value compared to other methods
6. Less steel consumption
7. Less concrete consumption for foundation
8. Lower risk

*From engineering point of view:*

1. Flexibility in structural design and architecture
2. Possibility of usage beside other systems
3. Ease of installation and implementation of facilities
4. Possibility of implementation in all seasons and various weather windows
5. Higher safety and discipline in workshop
6. Less monitoring required

7. Predictable cost and time for the whole system
8. High implementation speed
9. Ease of assembly and separation of wastes and low materials losses
10. Least manufacturing error

*From earthquake and lateral forces point of view:*

1. Less weight contribution due to lighter structure and using brand-new materials
2. Suitable behavior as a result of steel deformability
3. Standard mechanical connections
4. Braced walls and roofs
5. Reliable connection to foundation

*Other benefits:*

1. Resistance against weathering
2. High corrosion resistance
3. Reduced usage of heavy lift cranes and heavy machineries due to light weight of panels
4. Recyclability of the structure and other parts of the building
5. Having a workshop without any wastes
6. Continuous factory manufacturing
7. Providing suitable working conditions with high safety factor
8. Issuance of technical certificate at the end of project

**5. Various methods of investigation and study of light steel frames**

In recent years, a great deal of research has been carried out about light steel frames structures globaly. Most of these research activities are in the context of structural performance of various forms of thin-walled profiles or seismic evaluation of such structures. Different methods used for this purpose and they can be subcategorized into following groups [4]:

1. Experimental procedures and production of physical models
2. Numerical analyses by means of finite element software

Despite of well-documented results, due to need for production of numerous physical models and considerable time and expenditure wasting, experimental procedures are less preferred. In these methods, through repetition of a certain test on various physical models, it is attempted to achieve similar results.

Second method is using the finite element software such as ANSYS and ABAQUS. Such types of software are widely accepted by structural engineers due to their very high accuracy and ease of analysis [4].

## 6. Investigation of strengths and weaknesses of LSF structural systems

Results of studies show that weakness of LSF structural systems during strong earthquakes is mainly concentrated around connections of walls of the structural system. Some of these important connections are connections of vertical thin-walled sections (studs) and horizontal thin-walled sections (tracks), connection of walls to frame and connection of bracing members to wall frame. In traditional design methods, as a result of ignoring such connections in seismic design of this type of structural systems, they show some weaknesses during earthquake [4]. To prevent such weakness in above structures, following preventive actions can be taken into account [4]:

1. To reduce vulnerability of light steel structures against strong ground motions, connections of these structures specifically those corresponding to walls which are experiencing motions must be taken into consideration.
2. Using plates with thickness similar to vertical cold rolled steel members can reduce lateral deformation of structure considerably and meanwhile, it can reinforce the connection of bracing belts to wall frame.
3. Using connecting plates to connect bracing belts to light steel frames leads to significant increase in seismic energy absorption of the wall during serious earthquakes.
4. By stepwise increase in deformation of wall frame, lateral deformation of the wall increases gradually and stress concentration will be mainly limited to the connection of bracing to frame and the center of vertical studs.

## *7.* Investigation of the effect and role of LSF technology in economical aspect of the housing and economic sustainability of the society

In 1948, in its human rights global declaration, UN emphasized that: everyone deserves the right to benefit from required life quality to have health and welfare including food, clothing, housing and so on. In 1966, general assembly of UN approved an articles based on which conditions for appreciation of all peoples' rights for having an appropriate life for oneself and family including food, housing and life improvement are provided. Finally, in September 2000, general assembly introduced eight main recognized goals as millennial development goals one of which is considerable improvement of life quality of at least 100 million Slumdog persons by 2020 [5].

This issue was noted to attract attention to the importance of providing housing in international level. One of the issues which can be a key element for economic and social development is housing ownership which must be taken into account through methods such as industrializing the construction system.

In a research performed by some researchers, all residential houses constructed using LSF structural system in Qom, Kashan, Esfahan and Tehran are studied and assessed [5].

Following table summarizes materials, masonries and ancillaries that is required for construction of a 75 $m^2$ residential house by utilizing the LSF structural system.

**Table 1:** required materials and masonries for construction of a 75 $m^2$ house using LSF system [5]

| Material | Quantity |
|---|---|
| Steel plate | 2400-2600 kg |
| Roofix | 100-140 $m^2$ |
| Reinforcing bar | 600-700 kg |
| Window | 9-16 $m^2$ |
| Door frames | 5 |
| Doors | 4 |
| Entrance door | 1 |
| Sanitary ware | 2 sets |
| Concrete | 19-27 $m^3$ |
| Cement | 6.6-7.5 $m^3$ |
| Faucet | 225-280 $m^2$ |
| Gypsum board | 338-400 $m^3$ |
| Cement board | 225-280 $m^2$ |
| Sheet-metal screw | 8000-8500 |
| Key and plug | 30 |
| Insulation | 150-200 $m^2$ |

Results of above study illustrate that using LSF technology in construction industry is considered as an effective and economic method and technology in construction industry. By utilizing this system, which leads to provision of an economical house for all walks of life, economical sustainability of the society would be brought force. In addition, this method yields less wastes compared to other common methods of construction in Iran and brings about more environmental friendly method. According to results of this research, using this industrial method for construction in a developing country with high population growth rate like Iran, China, India can be a shortcut for access of people to housing and finally supply of sustainable housing for people [5].

**8. Benefits of LSF system compared to common and traditional methods**

1. Strengthening stage of the buildings after construction could be significantly reduced or even eliminated by utilizing the LSF system in constructions..
2. Due to light weight of LSF structures, lateral loads applied to the structure have less effect on the structure and this matter prevents future potential problems.
3. Rapid construction of these structures can provide residents with an economic, safe and resistant building.
4. Such buildings can show suitable reaction to natural phenomena and disasters. On top of that, it can be constructed and used rapidly.
5. High energy saving of these structures can make such plan in long term and with a deep look [1].

## 9. Conclusion

1. In modern society in which speed and productivity in every context is deterministic, application of rapid and optimal methods such as LSF systems in construction industry seems inevitable.
2. Due to the high seismicity level of the region in which Iran is located and high seismic hazard in Iran itself, it must be attempted to lead performance of structures toward least life and financial losses in case of earthquake.To achiving this goal, one of the useful method is using the LSF systems. In this regard, light weight and numerous load bearing members can reduce level of input earthquake energy to the structure.
3. As a result of limited resources and materials and owing to high cost of masonries in construction industry, using a novel method such as LSF can lead to reduction of construction expenditure through extension of this industry in large scale.
4. It must always be considered that the construction wastes should be minimized or even eliminated as much as possible. In conventional structural system, waste production s is inevitable though. In this respect, application of LSF system is possible due to possibility of reuse of used members in these structures and it must be taken into account more than before so that it can bring about a healthier environment.

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