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Constructional System of Cold Formed Light Steel Framing (LSF)

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Abstract. Nowadays, various methods are used to strengthen structures against earthquake. One of the new methods which can be used in improving seismic behavior of structures is to use light steel framing. Lightweight steel framing system (LSF) is a structural system which is employed to implement buildings which are mostly low and medium rise buildings (at most 5 stories). This system which is very similar to wooden structures' construction methods is constructed based on applying some constituents called Stud or Track. The main structure of the building is established from combining cold formed galvanized profiles. The purpose of the present study is to define, explain and apply lightweight steel framing as well as referring to required machineries and physical properties of the needed steel. In this regard, the requirements of design, execution, shell life, various stages of designing, foundation of building, internal and external coverings of ceiling and wall, electric installations, doors and windows are also discussed. Finally, advantages and disadvantages of lightweight steel framing systems are stated. The present project can be introduced as the most comprehensive and complete instruction for lightweight steel framing structural systems.

Keywords: new steel structure system, lightweight steel framing, light steel framing (LSF) design and execution

1. INTRODUCTION

Using the members of cold formed steel began from the 1850s but it was not widely used until the first dissipation of American association of iron in 1946. Today, due to appropriate quality of construction, high speed, and high resistance against earthquake, it is used in England, America, Australia, Canada, Japan, etc. these buildings consist of three main constituents including sections consisted of cold formed sheets for structure, plasterboard as internal covering, and acoustic and thermal insulation. These buildings as an independent structural system are mostly applied in mass construction of two-story buildings, small commercial buildings, industrial units, and one-story sport salons. It seems that this structural system of gravity load is also able to be combined with other structural systems such as structural reinforced concrete walls and can be applied to construct low rise buildings as mixed structural system. To construct cold formed sections, it is legal to use various shapes according to regulations related to these structures. The vertical components of this system act as column load bearing in gravity loads. Some of these members placed in the span of the structure's lateral restraining. In addition to gravity load, this system undergoes forces derived from lateral loads and these members are introduced as stud in the system. The ceiling of this building's structure consists of cold formed beam such that the distance of beams is determined with respect to load bearing capacity of the member and the dimensions of the ceiling covering parts which can be wooden or cement boards or reinforced concrete slab. Cold formed profiles have low resistance against fire and should be well protected. One of the causes of applying gypsumas internal covering of the system is to achieve this purpose.

Thin wall steel sections are galvanized steel sheets which are shaped using cold rolling and roll forming in factory. Based on the regulation formulated for cold formed steel sections, the thickness of the base steel (the thickness of the steel without computing protective coverings) has been formulated between 0.455 mm to 3 mm. Producing and cutting this section in factory

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causes that producing sections is performed with appropriate and uniform quality in very high volume and speed. Close distance of these steel sections to each other creates load bearing walls which have appropriate resistance and rigidity against lateral loads due to wind and earthquake.

Cold formed lightweight steel buildings are implemented through two general methods of stratified framing and continuous framing. In stratified framing method, the wall of the story is firstly implemented. Then, the ceiling, completing wall and ceiling framing, the wall of the upper story are implemented, respectively. In wall execution method, the walls are built and installed in several stories and then, the ceiling of the stories is implemented.

1.1. Applying Construction System of Lightweight Steel Framing (LSF)

Construction system of lightweight steel framing (LSF) is used in various types of constructions such as villas, residential buildings, administrative buildings (up to two-story), hotels, hotel apartments, schools and universities, restaurants, residential and recreational camps, etc. For example, it can be referred to multi-unit buildings, small commercial offices and buildings, sport and educational buildings, industrial units, half-story construction within high height constructions, developing the number of stories on roof of existing buildings, pre-casted applied spaces such as WC in the form of Box System, reconstructing regions damaged due to natural disasters (earthquake, flood, tornado, etc.) in terms of permanent settling, temporary settling of victims of natural disasters (given to low speed and cost of construction), and constructing small and inexpensive housing. On the other hand, constructing new residential towns (in the frame of mass building) by considering cultural, economic and geographical points in design as well as designing towns based on the last scientific achievements given to predicting urban needs by considering development design, and new construction in small towns and villages (such as residential, educational, cultural, etc.) are of the applications of LSF's construction system. In the following figure, a schematic of a building with LSF's construction system has been presented.

Figure 1. The schematic of a building with LSF's construction system

1.2. Construction Machineries and Characteristics of Allowed Steels

To construct buildings of LSF systems, simple machineries such as rail, pin firing guns, elevators, cut saws for steel and plasterboards are employed. Furthermore, there are various allowed steel sheets to be used in cold formed members based on ASTM A 1003 standard which are as follow:

- Structural steel row 230 type H (ST230 H)

- Structural steel row 240 type H (ST240 H)
- Structural steel row 230 type L (ST230 L)
- Structural steel row 240 type L (ST240 L)

As shown in Table 1, mechanical properties applied in structural and non-structural member used in cold formed frames are presented.

Table 1. Characteristics of allowed steels in LASF's system

Steel characteristic	Yield resistance (mp)	Final tensile resistance (mp)	Length increase in 50 mm
ST340H	340	450	10%
ST230H	230	310	10%
ST340L	340	-	30%
ST230L	230	-	30%

2. THE STAGES OF IMPLEMENTING CONSTRUCTION SYSTEM OF LSF

2.1. The first stage- design

Firstly, the primary plan (architectural plan) is provided based on the request and opinion of employer given to the form of villa (flat, duplex and triplex) or the form of two-story (apartment) and then, the provided architectural design is defined and located through computer software of main building skeleton (structure) including all details and computations involving resistances of wind, snow, earthquake, and various loads (live and dead), observing the distance of load bearing columns from each other, width and type of columns and beams. In this stage in which all the computations have been performed using software and according to certain standards, transmission path of all mechanical installations (warm and cold water) and electricity is also determined and punched out at the time of producing with certain machineries. All cuts and structural connections are designed and determined in this stage.The important point is that there is no limitation in designing and implementing pre-casted buildings and it can be designed and constructed in every design, map and dimensions which is based on traditional, modern and classic architecture.

2.2. The second stage- foundation

Foundation which is commonly used for cold framed lightweight steel framing's constructional system is stripe type or wide foundation, if necessary. In those buildings whose floor balance is lower than natural land, reinforced concrete walls can be implemented around underground as well as all internal load bearing walls. It should be noted that lateral rigidity of lower story's reinforced concrete should be at least 10 times as equal as the lateral rigidity of the upper cold framed steel structure. In this case, lightweight steel parts and reinforced concrete can be independently designed. It is necessary to pay enough attention to execute the upper surface of foundation in the form of balance without any defect to install load bearing walls. If, due to any reason, the upper surface is not balance, all the arrangements should be considered to create flat lead bearing surface between lower crack or peripheral crack and foundation. The maximum acceptable distance of foundation surface and load bearing walls' lower crack is 6.4 mm and this distance should be created by placing filler load bearing sheets or implementing grout filling the considered reinforced surface. None of the lightweight steel framings' members should be placed in direct touch with the earth; so, the framing should be installed in a distance upper enough from the earth through some arrangements. Direct touch of the wall's lower crack

or any other part of framing with new concrete should be avoided. For example, poly ethylene covering can be used to cover around cold framed part. The regulations of foundations' design and execution should be according to the ninth section of national building regulations discussion. Moreover, in this type of foundation, Art well execution- wastewater pipe and other cases can be seen.

2.3. The third stage- building structure

Each of the components of LSF's construction system includes different parts which are discussed in the following.

Wall: In lightweight steel structure, walls bear lateral and gravity loads. Walls are hollow and can fill this empty gap with lightweight concrete or polystyrene foam. These walls include load bearing walls and non-structural loads. There are two execution methods to construct walls framing in building. Framing load bearing walls can be constructed in the place of workshop providing to create a balance surface and appropriate chassis drawing. Then, the walls can be established in precise place. Another method is to produce a pre-casted panel in factory in which precasting ceilings, walls and trusses is performed through assembly tables and after transportation to the site, the operations of installing ready panels are performed. In both methods, implementing non-load bearing walls can be performed after implementing load bearing walls and ceiling.

Ceiling: The system of structural ceiling includes beam, peripheral crack, strap clips, integrating clips, and different types of covering such as wooden-steel structural plates. Also, it is allowed to apply compound concrete ceilings and steel board by observing the related regulations.

Trusses structure: Steel truss members should be precisely cut and appropriately connected together. The maximum empty space between hardener members is more than 12.7 mm. The situation of truss chord members, truss web and nodes should be implemented according to maps.

2.4. The fourth stage- internal and external ceiling-wall coverings

Isolation: Using the most favorable construction thermal and acoustic insulations with the modern methods, noise and heat exchange can be avoided in external walls. These techniques not only are able to adjust in every climate and conditions, but also they play an important role in energy saving.

External walls: To prevent any thermal and cold energy loss in buildings and external walls, compressed wool stone insulation is employed to totally insulate these constructions against cold and warm weather and moisture of the environment. Various insulations include ceramic, polystyrene, poly ethylene, and plastic insulations.

Internal walls: to insulate internal walls, polystyrene with the thickness of 5 cm is used.

Covering materials:

- Gypsum board
- Cement board and gypsum board
- Wooden panels and MDF

Currently, traditional materials such as brick and block are used in most of under construction buildings. These materials have their own disadvantages and executive problems.

In LSF structures, in addition to using traditional materials as external covering, another type of coverings are used as internal covering which mostly include gypsum boards, wooden panels or fiber cement panels. Introducing fiber cement panels in LSF construction systems: these panels are installed on galvanized steel structure and play the role of wall in all applications (such as internal and external walls, internal and external ceiling, etc.). Fiber cement panels are a new generation of constructional materials which have been widely used at internal and external levels of building during the two last decades. Good mechanical resistance and excellent resistance against moisture, vermin and other destructive factors have caused that these panels are welcomed more and more. As their application, it can be referred to internal partitioning, false ceiling, external wall covering, internal wall covering, and external ceiling. The dimensions of each panel is 1220 × 2440 mm and/or other sizes are customized. The thickness of those walls in which this panel plays the role of external wall is 8 mm. the outstanding feature of these panels is being fireproof. Using this panel in walls and partitions leads to protect steel skeleton of building against fire.

- Resistant against moisture, fire, beat, insects, and chemical materials
- Not having asbestos or any other harmful materials
- Not resulting environmental pollutions
- Easy installation, security, stability, light weight, and considerable durability

Wall and ceiling coverings: As wall and ceiling coverings in LSF systems, it can be referred to wall paper or poster, color, wall covering, ceramic, or antique stones and inscriptions.

Floor coverings: Floor covering can be used in parquet, stone, ceramic, granite, pavement, etc.

2.5. The fifth stage- electrical and mechanical installations

Mechanical installations: Installation pipes are based on using super pipe and compressed PVC which have more flexibility and longer life compared to metal and cast iron pipes. According to the opinion of employer, central ventilation system and package can be used for air conditioning system.

Electrical installations: Electrical installations include stretch wire-key-Art wall- phone line-TV cable-electricity table-plug which is possible in these types of buildings. In this method, plastic pipes are drawn from the upper part of false ceiling to the empty space between walls to the place of boxes which have been previously installed through specific buttress in the considered place.

2.6. The sixth stage- door and window

Doors: Using various types of doors- MDF, HDF, UPVC- and fireproof and anti-theft aluminum (doors framework is of steel or wood).

Windows: Using various types of UPVC and/or aluminum windows with single-wall and double-wall glasses in thickness and dimensions and various shapes

2.7. Advantages of LSF Structures

Very high implementation speed: LSF method allows investors to gain back their capital in the shortest time with the best quality of construction. For example, for constructing a 4-story building with a foundation of 1000 m^2, 114 working days are needed. It has an increase of 8% to 13% of useful internal space compared to traditional method.

High and uniform quality: due to the fact that structural sections of this system are produced and cut in factory and implemented then by technical technicians, the final product quality is very higher than traditional construction.

Light weight and the decrease of earthquake force imposed on structure: structural weight of this system is about 25%-30% of normal structures. Accordingly, they absorb very less earthquake force to the same proportion.

High quality of connections' implementation: unlike traditional constructions in which low quality of connections is the source of most of damages due to earthquake, simple connections have high executive quality in this system.

Having universal standards of energy consumption: compared to traditional structures, energy transmission percentage is very less in these buildings in terms of appropriate walls insulation in LSF system. In long term, it leads to a considerable saving in the cost of heating and cooling.

Easy transportation: light weight and small size of sections cause to the easy transportation even in impassable points.

Recyclability of most of materials: most of structural and non-structural components in this system are spirally implemented and they can be easily recycled. Near to 70% of materials can be replaced.

High resistance and durability against unfavorable environmental conditions: due to the galvanization of all sections, buildings constructed by this method have more appropriate resistance against erosion and moisture and they will have more shell life in environmental conditions of north and south.

Easy implementation of mechanical and electrical installations: in the process of shaping and making thin-wall steel sections, standard holes are predicted in the web of these sections such that passing wires and pipes through which cause to facilitate installing electrical machines and piping within walls.

Cultural accordance of internal environment and façade with traditional buildings: there is the possibility of implementing color, wall paper, and so on in various facades such as stone, brick, wooden or aluminum PVC, color, ceramic, etc. and in internal space similar to typical walls at external surfaces. Such a feature prevents any difference between these buildings and common buildings.

Good acoustic performance: the insulation within walls causes not transmitting sound, leading to appropriate acoustic performance of these buildings.

Having standards and regulations of being fireproof: all the elements of this system such as thermal and acoustic insulations possess fireproof standards.

The need of low workshop space and more security in workshop: given to simple equipments to implement such systems, there is no need of big workshop spaces.

2.8. Disadvantages of LSF Structures

Totally, the disadvantages of LSF structures can be stated as follow:

- There is a limitation in the dimensions of span.
- The number of stories which can be constructed with this system is limited.

- There is a need of expert labor force.
- Supplying galvanized metal parts produced in factory has a high cost.

3. CONCLUSION

Nowadays, various technologies are employed to create ease and comfort, more security and saving in costs, especially in energy resources consumption. In the performed studies on LSF system with other systems, the following results are presented: Using cold formed steel sections is followed by many advantages. The most important advantages are the lack of need to using thermal operations, lack of thermal tensions of residual in sections, the possibility of creating sections in various shapes to achieve the maximum resistive return in section, light weight, high resistance and rigidity, high accuracy in implementing details, and rapid and easy installation.

As the research findings revealed the amount of base cut in LSF system compared to reinforced concrete system is reduced up to 55.5% and compared to metal system is reduced to 38.1%. The highest amount of displacement of the roof mass center in LSF system compared to reinforced concrete system is decreased to 56.2% and compared to metal system is decreased to 38.1%. The total weight of building in LSF system compared to reinforced concrete system is decreased to 572.8% and compared to metal system is decreased to 58.7%. The amount of building skeleton weight in LSF system compared to reinforced concrete system is reduced up to 72.4% and compared to metal system is reduced to 55.8%. The amount of consumed concrete in LSF system compared to reinforced concrete system is reduced up to 78.9% and compared to metal system is reduced to 56%. The amount of consumed steel and reinforcement in LSF system compared to reinforced concrete system is reduced up to 24.5% and compared to metal system is reduced to 54.3%.

LSF construction system is formed using industrial construction production method and using double-layer walls. Therefore, there is an appropriate system for each type of insulation. In case of appropriate supporting, using a system with these potentials, thus, can be followed by sustainable development in building sector accelerating constructions, industrial building production in the country, optimal use with the possibility of recycling constructional materials. It can be also used as an appropriate method for thermal insulation without implementation cost, influencing load bearing in construction with the capability of optimal energy consumption control, and cultural effects in the way of using natural resources and accuracy in constructions.

Considering the obtained results, it can be stated that using this kind of construction require high attentions to a certain part of structure. For instance, it can be referred to the high importance of connections in cold formed connections. Observing necessary factors and regulations obtained from the previous studies, the implemented structure can obtain specific features such as the decrease created in structure's displacement, high energy absorption capability due to earthquake, and restraining tension concentration focus in specific parts of structure.

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