LSF Technology in Building Design & Construction
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ABSTRACT
The adopted strategy to overcome the housing shortage crisis in Iran is the mass production. The way forward to accelerate the mass production, is adopting the industrial building systems with the increased prefabrication. One of the most optimal new building systems is Lightweight Steel Framing (LSF) Technology. Parand Residential Complex as the first serious project to industrialize the construction processes in Iran is facing the various problems during the processes of manufacture and execution of LSF components. The research is to offer an optimized model for the manufacture and execution processes of LSF Technology in the constructive projects. So, the manufacture and execution processes of LSF Technology in the research case-study were taken into consideration to recognize the existing advantages and disadvantages. Finally, offering four strategies to compensate the deficiencies and three strategies to intensify the strengths, a model to coordinate these two processes presented.

Introduction
In the recent years, with the considerable rise of housing demand, introduction and dissemination of new building systems for mass construction has become an urgent necessity. In the search for new constructive methods and materials for residential and commercial buildings, where the quality of living, ease of construction, and cost-efficiency could be improved, cold-formed steel has been an attractive alternative to the traditional materials [2], due to the following reasons:
1. The rapid constructive process at the special economic and geographic conditions.
2. The building’s reinforcement against the earthquakes.
3. The proper control of construction’s quality.
4. The construction’s high-speed to overcome the housing shortage crisis.

Lightweight steel framing (LSF) Technology
There have been significant developments in the technology which result in more complex shapes with a higher yield stress so that cold-formed sections represent a particular high-tech form of constructional steelwork [3]. Lightweight steel framing (LSF) as an increasing popular choice in low to medium rise structures is adaptable to numerous applications traditionally constructed with hot rolled structural steel, wood, masonry or other conventional materials. It alone as a versatile structural product can provide all necessary structural elements or can be used in combination with other materials for greater building diversity and scope. Such a constructional system which has got many similarities to the wooden structure techniques is based on the elements named Stud or Track (Fig.1). Because of the comparative thinness of the material, connection technology plays an important role in the development of structures formed using cold-formed sections. The conventional methods of connection, such as bolting and arc-welding are of course available but are generally less appropriate and the emphasis is on special techniques more suited to thin material. Long-standing methods for connecting two elements of thin material are blind rivets and self-drilling, self-tapping screws. Fired pins are often used to connect thin material to a thicker supporting member [4]. Such a technology is used in load-bearing and curtain wall construction, floor and roof assemblies, mansard and truss frames, as well as interior nonstructural partitions. In curtain wall applications, the reduced dead load of the exterior wall as a result of using steel studs in lieu of masonry may result in primary structural frame and foundation material savings. Exterior retrofits are less likely to require expensive reinforcement of the existing structure. In load-bearing construction, a lightweight steel framing system is a benefit when the site is plagued by poor soil conditions. Mid-rise residences requiring unique ground level construction (parking structures, meeting or dining facilities, etc.) benefit from the reduced dead weight applied to the supporting structure. Whether used as curtain walls, floor joists or roof rafters, or in mansard and truss frames, axially loaded partitions, headers, beams, etc. steel framing works well independently or in combination with other structural systems.
Research Case-study

Parand 550-unit Residential Complex as the largest Iranian constructive project by the use of LSF technology has been adopted as the research case-study.

Research Goals
- The recognition of manufacturing process.
- The recognition of executing process.
- Modeling an optimized process of manufacture and execution of LSF technology in the constructive projects.

Manufacturing of Cold-Formed Steel (CFS) Products for Parand Project

Generally, Cold-Formed Steel (CFS) is the common term for products made by rolling or pressing thin gauges of sheet steel into goods, using stamping, rolling, or presses to deform the sheet into a usable product.

In Iran, C cannels or U cannels profiles are the most optimal profiles to manufacture CFS Products, because of their simple form and cost-efficiency. So, such profiles are considered as the only available option for the constructive projects using LSF technology. They are formed using the mechanical techniques without any pre-heating process. The rolled coil steel is opened by a Coil Opener machine. The function of Coil Opener machine is to open Coil & Straightening to feed into turning pointing machine and then into schumag or Bull Block Machine for drawing from wire Rod Coil. Then the rolls will be punched by a Hole Puncher and formed through a break press process. At the last step of the production line, the profiles will be cut at the certain lengths. Such a process is designed schematically in the following diagram (Fig.2)

Fig 2. The production line of steel profiles by the cold roll-forming (Reference: the authors)

The Execution Process of LSF System in Parand Project

The execution process of LSF Technology in Parand Residential Complex is as follows:

1- Foundation: The foundation of the buildings, constructed by such a system is the stripped foundation which is placed under the load-bearing walls.

2-wall: Usually all the walls are designed as the load-bearing walls; but if a patrician be needed, a dry-wall can be used. All the walls are attached to the foundation by a U cannon and to the ceiling by a U runner. Therefore, the studs as the vertical C cannels are attached to these two runners, using welds, bolts, or self-drilling screws. To create the intel above the openings, usually two C cannels are attached to each other.

3- Lateral Bracing: K braces and X bracings (cross bracing) are used to increase the lateral stability against the lateral forces.

4- Roof: The roofs in this system are the sloping or flat roofs. The main structure of such ceilings like the walls is C cannon or Z cannon. The covering materials of the slopping roofs are the light materials such as plywood or board. The flat ceiling as the roof or floor is a light ceiling and in some cases a composite ceiling.

5- Thermal Insulator and Fixture: Thermal insulator can be installed by two methods:
- The studs are set parallel and the thermal insulators are set in the middle spaces.
- The studs are not set parallel and the wall is constructed using the separated frames. In this method, the thermal insulators are placed in the middle of studs in a zigzag form. The raceways or conduits are set between the thermal insulators too.

6- Facade: various kinds of facades can be constructed in this system, using the insulating gypsum lath, cement board, gypsum wallboard and even stone or brick (Fig.3).

Fig3. The construction process by LSF Technology (Reference: the authors)

Recognition of Advantages & Disadvantages of LSF Technology through the Manufacture and Execution Processes in Parand Project

Parand Residential Complex is the first serious project to industrialize the construction processes in Iran. Such an issue is considered as the main success of the project which entailed the next successes, including:
1- Establishing the factories to manufacture LSF components and localizing the technology.
2- Providing the houses for the low-income strata of society with more speed and quality.
3- Creating the job opportunities at the manufacture and execution processes.

In spite of achieving the considerable successes at the manufacture and execution processes, the defects are not deniable. The most considerable defect is the poor supply chain management, causing the following problems:
1- Lack of compatibility of the workforces and the produced LSF components. For example, the LSF components related to one group of workforces are ready, but because the LSF components related to another group are not ready, the project is stopped.
2- Lack of compatibility of LSF components’ size and the designed samples by architects (in most cases, the pre-fabricated components are cut).
3- Lack of compatibility of LSF components’ form and the designed samples by architects because of factory’s deficiency to manufacture the diverse components.

Fig 4. Coordination model between the manufacture process and the execution process
Conclusion

According to the accomplished studies on Parand Residential Complex as the research case-study and the recognized advantages and disadvantages, a model can be proposed to coordinate the manufacture and execution processes. Such a model is the resultant of the requirements of architectural design or LSF manufacturing on the one hand and the requirements of proper or systematic execution on the other hand.

Based on the research analyses, the following strategies to compensate the deficiencies through LSF manufacture and execution processes can be suggested:

1- The accurate estimate of the required LSF components and workforces to construct a specific building.
2- Setting a weekly schedule for the project process to determine the exact number of required LSF components in a short term.
3- Through the detailed architectural designs, the exact size of LSF components can be determined. Then, such predetermined sketches would be available to the Production Unit. Applying such a method optimizes the time and energy during the installation processes of LSF components.
4- Equipping the Production Units to manufacture the diverse medullar forms to construct the buildings with the varied space-qualities.

And to intensify the strengths, the following strategies can be recommended:

1- Increasing the number of manufacturing factories to achieve the Self-sufficiency to provide the projects’ required LSF components that not only reduces the projects costs, but also coordinates the manufacture and Execute processes.
2- The precise time and workforce management to accelerate the constructive projects through determining the perquisite steps and the steps which can be done parallel.
3- Employing the workforces with the various specialties to take all the different requirements of the projects into consideration, from the project management to the project execution.

The coordination model between the manufacture process in the factory and the execution process in the executive site is as follows: (Fig.4)

References