A Research For Light Steel Construction Systems In Terms Of Changeability/Adaptability

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Abstract

Because of functional and technical obsolescence of buildings, speculative conditions and changes in the owner's demands, existing buildings are increasingly being repaired, adapted or demolished. Construction, renovation and demolition cause excessively resource consumption and waste generation, which have several environmental, economic and social impacts. Changeability and adaptability are one of design approaches that guarantee careful dismantling of a building so as make possible the recovery of construction materials, components and elements promoting reuse and recycling. These approaches were emerged as an alternative to demolition in consequence of increasing environmental concerns and rapid increase in the number of demolished buildings. The basis of this paper is to changeable and adaptable approaches for light steel construction systems which deal with buildings that can be changed, adapted and eventually even dismantled without leaving any debris on site. The changeable and adaptable approaches are discussed and evaluated on some case studies.

Key words: Changeable and adaptable system, disassemble, light steel construction.

1. Introduction

Changes and development of characteristics of building owners and users, socioeconomic status or occurring in the life style, cause locational, functional, technical and economic obsolescence in existing buildings, in this case, changeability and adaptability of building gain value. Besides these processes, building construction operations occur a large amount of structural waste, this waste, which leads to further deterioration of the ecological environment and growing environmental pollution. Due to increasing these problems, changeable and adaptable building systems have been created to respond the future needs.

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2. Changeability/Adaptability

Throughout the history of architecture, there has been an increase in the complexity of the building as a whole as well as in the individual components. The more specialized a building is, the less multifunctional it will be. Knowing this has led to more multi-purpose, less specialized buildings now being constructed. When considering the entire building system, structurally there are three subsystems to differentiate: The primary structure is a long-term investment (50-100 years) that can only be altered with considerable effort. This includes the building envelope, supporting structure, installation systems, local infrastructure and access. The secondary structure is a mid-term investment (15-50 years) and can be adapted. Amongst others, it consists of non-load-bearing interior walls, floor structures, ceiling elements, the building technology system, communication technology system and lighting. The tertiary system is a short term investment (5-15 years) and can be altered without major constructional changes. It include, for example, the appliances, fittings and furnishings. In adaptable construction, these three subsystems should be aligned to each other but still function independently-on both the planning as well as the physical levels. This has the advantage that each subsystem can be planned and realized separately. However, it also requires a clear definition of areas where individual systems overlap. In this way, building performance is higher because of the “flexible” nature of contractual relationship between system suppliers as contractors and as clients, the building owners and users. Outsourcing enables owners and users to directly commission specific services. Viewed cyclically, the building is planned for a certain lifespan and the single elements are commissioned by the users themselves [1].

2.1.Design Typology

Working with types makes it possible to record a variety of adaptability characteristics in building construction and to use these to develop a classification system for adaptable buildings. In this way, it is possible to distinguish between adaptable and less-adaptable buildings and allocate them to the system [1]. Lightweight steel construction systems are classified in terms of additions to the facade and interior arrangements as extension and interior adaptability (Figure 1).

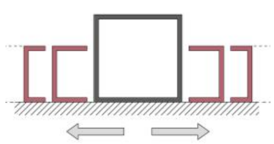
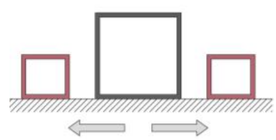
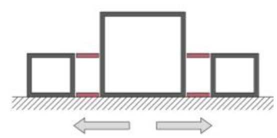
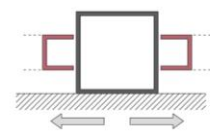
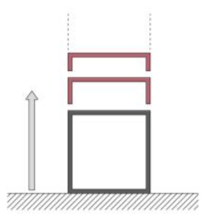
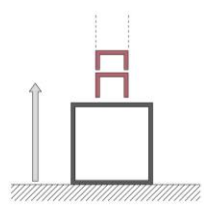
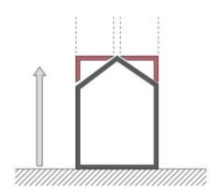
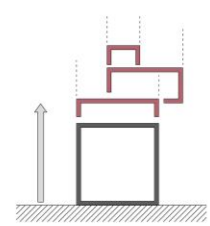
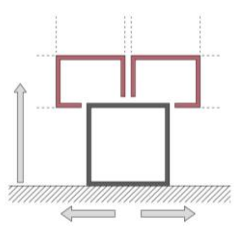
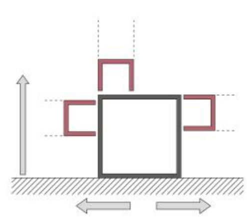
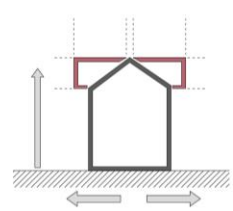
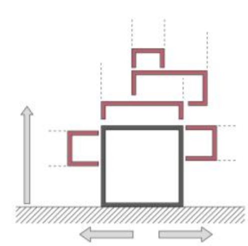
Figure 1. Mixed used for light steel system, (URL-1)

In this study, changeability of light steel system are discussed in two headings.

* *Extension Adaptability*
* *Internal Adaptability*

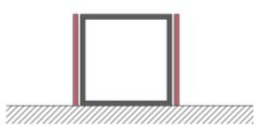
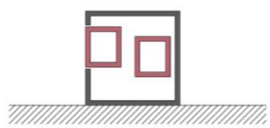
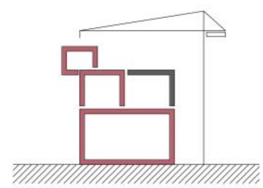
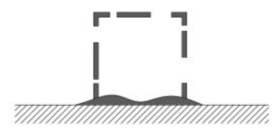
Extension Adaptability is based on the factors of expandability and refurbishment. The direction in which a building can be expanded is explored, as are which structural characteristics make an extension or renovation possible (Table 1) [1].

Table 1. Types of Extension Adaptability (Adapted from [1])

Horizontal Exteension	 Horizontal Extention	 Adjacent	 Above, as a fill-in within the existing courtyard	 Nuclear
Vertical Extension	 Vertical Extention	 Above, set back	 Above, as an attic conversion	 İntegrated all types
Vertical and Horzontal Extansion	 Above, as a cantilever	 Granular	 Above, as an attic	 İntegrated all types

Internal Adaptability defines the capacity for changes in a building: the extent to which adaptions, renovations or modifications are possible within the existing structure; the amount of time and effort required; the underlying risk; the influence of the combination of the single building parts (Table 2) [1].

Table 2. Internal Adaptability (Adapted from [1])

			
Facade facelifting	Retrofitting	Renovation/Extension	Demolition

3. Light Steel Construction Systems

Light steel construction system produced steel strip cut from cold formed sheet metal.
This steel strips are elements, manufactured by pulling with a tape among cylinder or bending with presses to profiling. Especially after the 2nd World War, cold-formed profiles were began used widely in the US, used in one or two-storey buildings. Present in the light-steel structures building can be constructed 4 times economical way. The required more high buildings, are often built on a steel frame structure system [2].

* Very low weight
* Accordance to the tolerance
* Assembly production allowing to short the time of construction site
* Have high rate of reproduction and the potential of reassessment for all the material used in the system
* Fire resistance
*Accordance to pre-production

One of the most important advantages of the light steel construction techniques is less structural weight according to other systems. If extra floors are planned to construct, because of the bearing of the ground floor cannot be increased economically, the light steel construction system can give the most appropriate solutions in these cases. Removable steel structure connections are based on the structures and structure types are called open steel structural systems are seen as promising future building systems. As defined in the name of the third-generation construction system, these systems consist of the building systems developed in all circumstances and independent of project and produced by mass production methods. Open construction systems allow more flexibility and design freedom than other construction methods. As with production of cars, the light steel systems have high level of variety and more solutions for specific design and planning with a small number of structural elements. The quality of such systems is determined by freedom of design, specifications and the economics of the overall system [2].

1.2. Types of Light Steel Construction System

Light steel construction system organized in three different ways:

**Stick-Built construction*
**Panelized systems*
**Modules systems*

Stick-Built Construction
The steel materials are delivered to the job-site in stock lengths or in some cases cut to length. The layout and assembly of steel framing is the same as for lumber, except components are screwed together rather than nailed (Figure 2,3).

Figure 2 Light Steel System, (URL-2)

Figure 3 Light Steel Structure, (URL-3)

Panelized Systems
Panelization consists of a system for pre-fabricating walls, floors and/or roof components into sections. Panels can be made in the shop or in the field. This method of construction is most efficient where there is a repetition of panel types and dimensions. Due to light weight of panels, they can be delivered and mounted easily by 1 or 2 workers (Figure 4) [2].

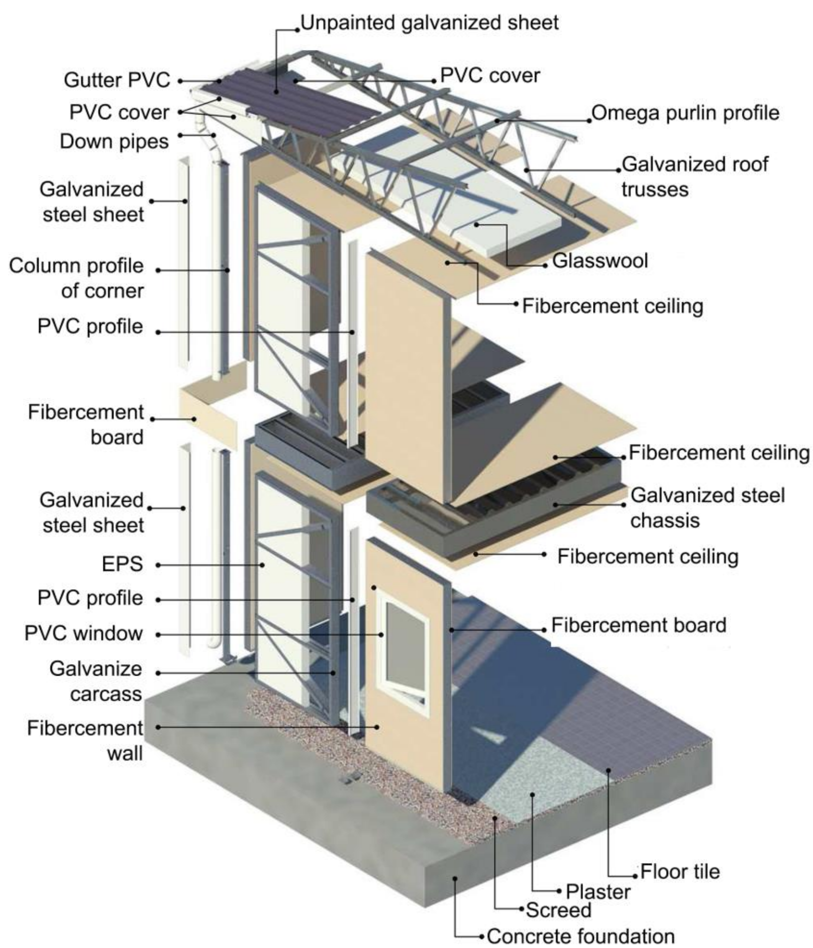


Figure 4 Panel System (URL-4)

Modular System
Modular construction is a term used to describe the use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building. The modular units may form complete rooms, parts of rooms, or separate highly serviced units such as toilets or lifts. The collection of discrete modular units usually forms a self-supporting structure in its own right or, for tall buildings, may rely on an independent structural framework (Figure 5) (URL-1).

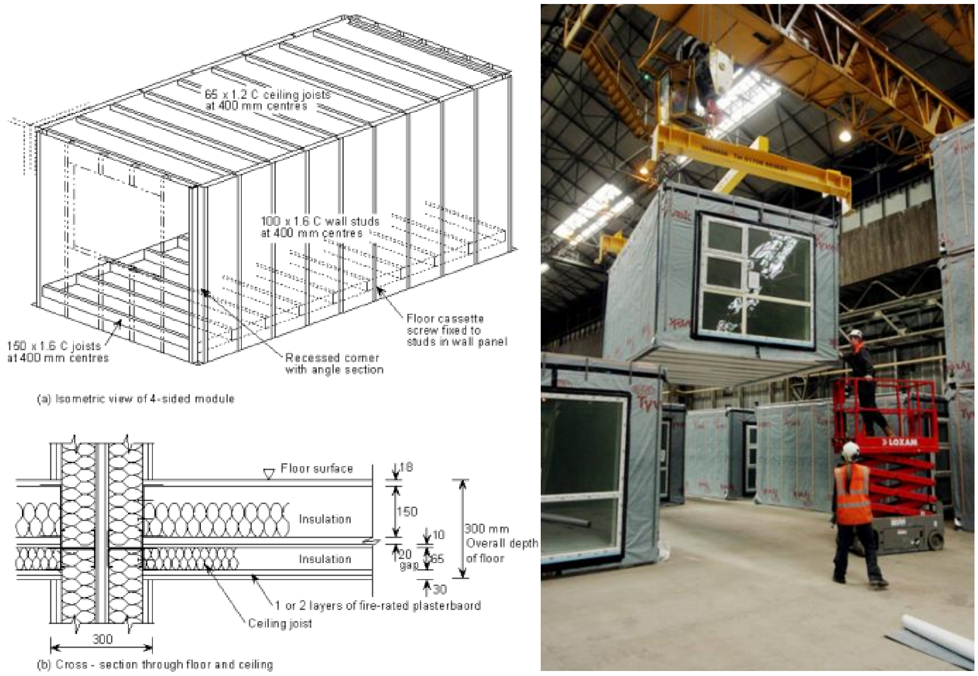


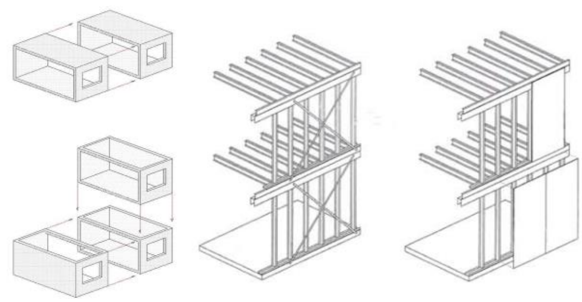
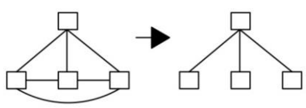
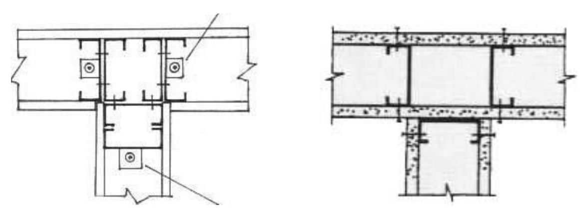
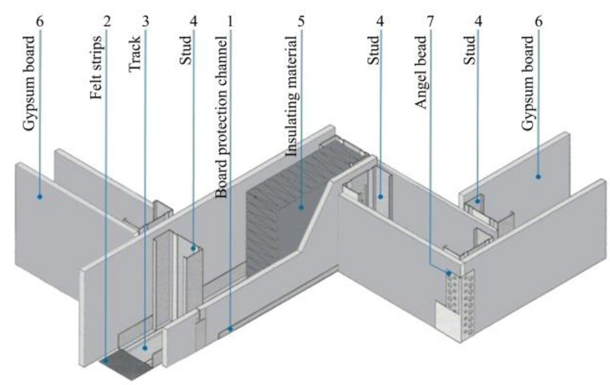
Figure 5 Modular System (Url-1)

4. Adaptability of Steel Construction System

A structure can be transformed if its elements are defined as independent parts of a building structure, and if their interfaces are designed for exchangeability. One can define independence of building components and their exchangeability as two key performance criteria for transformable structures. Independence of parts is determined primarily by functional design domains, which deal with design of material levels and specification of clusters. Exchangeability of parts is defined predominantly by technical and physical design domains that deal with hierarchical order of elements within structures, and with connections between elements. Although these three main domains of structural decisions concern design of transformable structures, they cannot be made independently of decisions regarding interface geometry, functional integration of parts within sub-assemblies, functionality of intermediaries, materials in connections, and life cycle co-ordination of material and their functions (Table 3) [3].

Four main building functions are: supporting, enclosing, servicing, and partitioning. Each of these can further be subdivided into subsections (subsystems) such as: foundation, frame, floor, façade, roof, inner walls, ventilation, heating system, water system, electrical system, etc. Each of these functions has different behaviours, and provides different effects such as: heating, reflecting, distributing, ventilating, lighting, or deals with effects such as tension, compression, etc [4].

Table 3 System composition (Adapted from [4])

 Functional Decomposition	 (Functional Decomposition Of Light Steel Construction System [5])
 Open Versus Closed Hierarchy	 (Open Versus Closed Hierarcy Of Light Steel Construction System [5])
 Assembly Sequences	 URL-5

Therefore, integration of two or more functions into one component can freeze transformations that may be needed to address new user requirements. The more elements are systematised into independent assemblies according to their functions, the easier is the life cycle and functional coordination between them. Therefore, assembly and disassembly sequences are easier to plan. Static configurations correspond to the building structure represented by the maximal integration of all material levels resulting in one building level. This is the case when materials are used on site. Totally decomposable structures are dry assemblies, in which material levels of technical composition, and parts within material levels of technical composition can be separated [4].

Base element specification

A building product is a carrier of specific functions or sub-functions. Each assembled product represents a cluster of elements that are carriers of sub-functions. To provide independence of elements within one cluster from the elements within other cluster, each cluster should define its base element, which integrates all surrounding elements of that cluster. Such elements share their functions on two levels in buildings: (i) to connect elements within independent assemblies, and (ii) perform as an intermediary with other clusters [4].

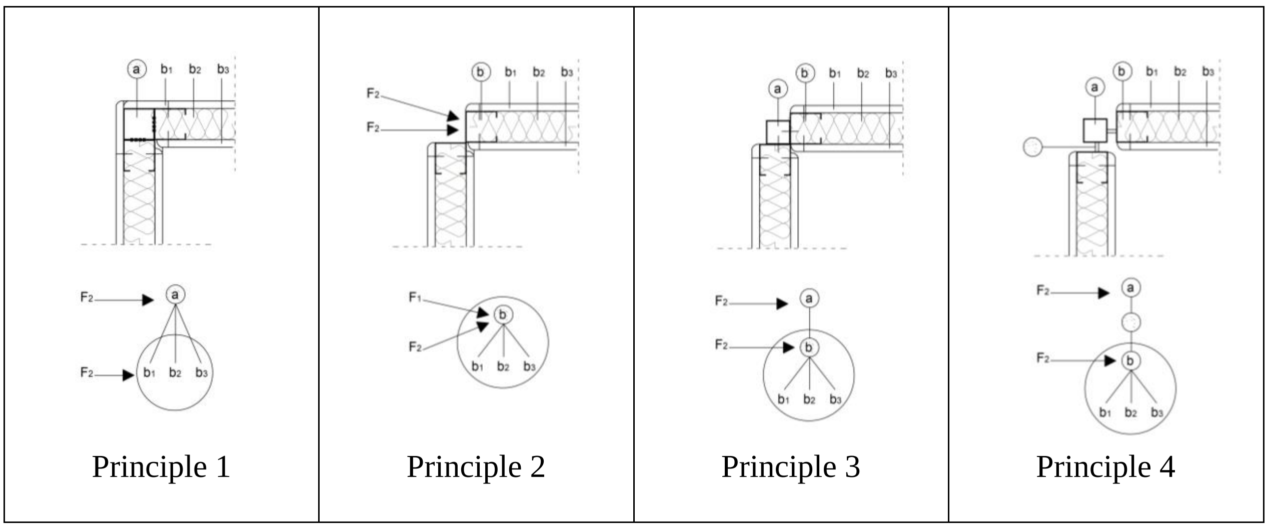


Figure 6 Four principles of base, (Adapted from [4])

Principle 1 in Figure 6 is based on the assumption that building parts are assembled on site. In this principle, elements, which according to their functionality belong to the functional assembly of the façade (f_1), have direct relations with other functional assemblies (load-bearing construction) (f_2). Column (a) has the function of the base element for all elements in assembly, and therefore has connections with them all. In principle 2, two functions (f_1, f_2) are clustered into one component. The steel frame (b) is the base element for the façade assembly and at the same time has a load bearing function in the building. This makes the construction process simpler; however, change of one façade panel would have consequences for the stability of the total structure. Principle 3 shows an independent assembly of two independent functions (f_1, f_2). Elements assembled as façade (b, b_1, b_2, b_3) are clustered into one component, where the steel frame (b) is chosen as the base element. The load-bearing function (a) is taken out and defined as an independent assembly. In this case, the load bearing elements act as a frame for the whole building and the steel frame b is the base for the façade assembly. This serves as an intermediary between the load bearing assembly and independent elements of the façade. In Principle 4, a connection has function of intermediary between two independent assemblies. In this case, the replaceability of a façade element (b, b_1, b_2, b_3) would not have an effect on other assemblies [4].

5. Conclusions

The building components produced as module or panel in factory, are combined to manufacture the light steel construction with simple assembly. According to the needs, lightweight steel construction systems offer more flexible solution conventional building systems. Depending on user needs, light steel construction systems offer variety of flexible solution building interior and exterior surface. To make changeability and adaptability of light steel construction system, building elements which form building system, are made independent form each other and system easily. Sequential assembly sequence was applied to independence elements from each other at the connections.

Reference

[1] Cowee, N. P., & Schwehr, P. (2012). The Typology Of Adaptability In Building Construction. Berlin, Germany.
[2] Eren,Ö. (2014), Hafif Çelik Yapı, Tasarım, Konstrüksiyon, Uygulama, Arı Yayınları,İstanbul
[3] Durmisevic, E., & Brouwer, J. (2002). Design Aspects of Decomposable Building Structures, Design for Deconstruction and Material Reuse. Karlsruhe, Germany: Proceedings of the CIB Task Group 39.
[4] Durmisevic, E. (2006), Transformable Building Structures, Design for disassembly as a way to introduce sustainable engenieering to building design & construction, Cedris M&CC, Netherlands.
[5] Ekinci, S. (2006). Hafif Çelik Yapim Sistemleri Taşiyici Sistem, Yapi Fiziği Etkileri Ve Mimari Tasarim İlkeleri Açisindan Analizi. İstanbul.

URL-1 http://www.steelconstruction.info/Modular_construction
URL-2 http://www.steelife.com.tr/Sayfalar/17/Teknolojimiz/Yapi-Sistemi.aspx
URL-3 http://www.steelife.com.tr/Sayfalar/17/Teknolojimiz/Yapi-Sistemi.aspx
URL-4 http://www.seckinprefabrik.com/hizmetler/hafif-celik-yapilar/
URL-5 http://www.hafifcelik.com.tr/hafif-celik-dolgu-duvarlar.htm