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Definition of Common Conventions for Education of CFS System Design

Semih Göksel Yıldırım

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Semih Göksel Yıldırım [1]

Abstract

CFS system of which can be used in the field of low rise residentials, are included in industrialised building systems due to installation principles of the system. Widespreading of the usage of an industrialised building system depends on the widespreading of the system design datum. Therefore, education of CFS system design is required in order to increase the system usage.Also, awareness of CFS system in the levels of public authorities and technical staff can be increased by education. The aim of this paper is to develop an education model for CFS system design by using open building concept. The system design education is being executed on the limited number of layout types by using the system catalog. The education model can be used by undergraduate students of architectural and civil engineering departments and graduate architects and engineers whom interested in CFS systems. Prefabrication principles and open building concept are being used in education of CFS system design. Distinguishing of design, fabrication and installation is only possible with definition of common conventions which can be used in different levels. Structural component types are limited and catalog datum are defined by getting help of the experience of furniture and toy industries, such as İkea and Lego, scaled model of machines. The industrialised building systems as NEN in Netherland, ACC and Solfege in France and BES in Finland are distinguishing designers and structural component producers by defined common conventions and limited number of components in conformity with open building concept.

Keywords: Building industrialisation, open building, design education of building components, common conventions

[1]Assist. Prof. Dr., Istanbul Arel University, Turkey, semihyildirim@arel.edu.tr

Introduction

Cold formed steel framing system had started to be used in Turkey after 1999 İzmit earthquake by getting know-how from North America. Number of firms, serving at the phase of design, production and on site installation, increased during time. Demand to low rise residentials is still continuing at significiant rate in Turkey and cold formed steel frame system seems to meet existing demand for low rise residentials. Approximately 600.000 residential units production including renovation is required annually in Turkey due to existing speed of population growth. 85 percentage of existing building stock is low rise buildings with one to three storey [1] [2]. Production capacity of S,T,U,F,L members in Turkey meet the demand of CFS system industry of Turkey. Producer' s of galvanized profiles for cold form steel framing produce similar components as quality and dimensions in Turkey by using North American' s codes and specifications during production phase.Production and usage of galvanized steel profiles for CFS system construction is in conformity with international standards.Leading firms of CFS system in Turkey got their know how from North America is the reason of wide usage of North America' s specification instead of Eurocode in Turkey.

CFS system is more costly than other low rise construction systemsin Turkey because of limited number of firms,little market volumeand little awareness at the level of technical staff. In order to become widespread of this system in Turkey , awareness in the levels of public authorities and technical staff shall be increased.In addition, furnishing widespread of CFS system is possible by supplying price competition and also,this could be possible by increasing of number of serving firms and technical staff at CFS system industry. Therefore, education of light steel framing designshall be run basically at the level of bachelor of architecture and civil engineering. Particulary, building component design courses in department of architecture are suitable for this purpose and design education of CFS systems can be put into this course. Prefabrication and open building concept help to systematization of this kind of education as system design.

Cold formed steel framing system can be designed as an open building systemwith limited component by using a common convention shown on a system catalog like NEN codes in Netherland, ACC and Solfege codes in France and BES codes in Finland, and so, manufacturers and designers can seperately contribute to the designed system. These codes refers to distinguishing of levels and modular coordination of building system with other sub-systems. It is possible to implement this approach to design education CFS system by defining of common conventions.

Prefabrication and Open Building Concept

Transferring of experiences of furniture and toy industries to building industry takes an important role in industrialisation of building. Meccano is a model construction system comprising re-usable components and it enables the building of working models and mechanical devices in toy industry [3]. It was invented in 1901 in England and the principles and the name was used in industrialisation of building in 1960’ s. Similarly, re-usable components are used in Lego Architecture and installation with defined components is done by customer in Ikea furniture concept as shown in Figure 1.User manuals help to installation of these systems. You can select your furniture in IKEA outlets and put them together all by yourself.

Figure 1. Meccano, Lego Architecture and Ikea furniture concept [3] [4] [5].

Industrialisation in construction is required due to technical and economical reasons as being in toy and furniture industry. The existing strategies for industrialisation in construction can be divided in two categories, each with its own typical approach as on-site and off-site industrialisation. On-site industrialisation refers to the application of advanced tools and technologies on buildings sites. Most on-site industrialisation is possible without design changes. Off-site industrialisation is based on the assumption that buildings may also be made in factories. Anothersplit in industrialisation strategies may be: product industrialisation and process industrialisation [6]. Standardization and distingushing of building to sub systems is the basic notion of building industrialisation as shown in Figure 2.

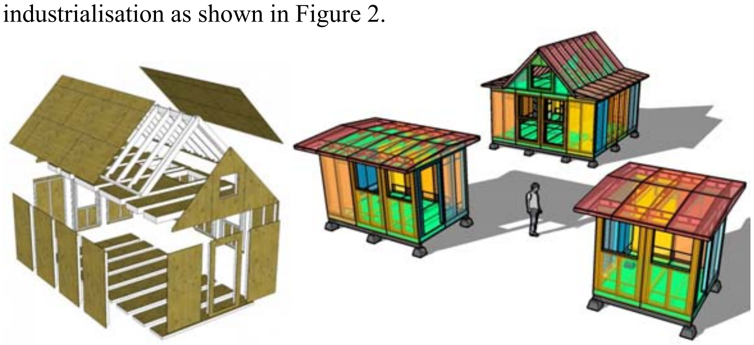

Figure 2. Building industrialisation [7] [8].

Re-distribution of design control is the field of industrial systematization. Design, production and installation processes are distinguished between designers and manufacturers by common conventions in “open building” concept. Building systems are separated as support (base building) and infill (fit-out) level in Figure 3 and “support” refers to structural system and envelope of a building and “infill” refers to partitioning walls, kitchen systems, utility systems and etc. These systemsare designed separately from each other in open building concept [9]. The role of designer in open building concept is; designing by using common conventions with limited number of components independently from the manufacturer [10]. Dimensions and positions of the components are determinative while consisting of geometrical shape of the building during design phase [11]. Open building implementation implies a new approach to architectural education. A number of schools of architecture around the world are experimenting with it. Because open building rejects functionalism, educators who teach open building help students develop skills in making built form, at various levels of intervention that can accommodate changing function [12].

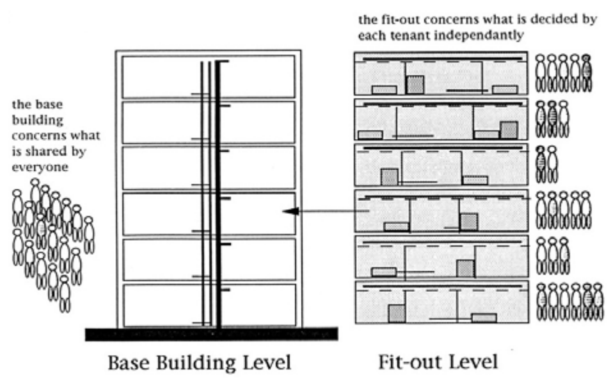

Figure 3. Distinguishing of levels in open building concept [13].

Modular coordination

Rules for dimensions, position and interfaces of building parts is a prerequisite for open building. Based on Habraken's book 'Support, an alternative to mass housing' [14], later the SAR (foundation for Architectural Research) published SAR '65. Based on the basic module of 4 feet (10 cm) a 'tartan-grid' was developed [15]. Later on SAR, research groups as OBOM and CIB workgroup W104 were formed.

To use a grid as a design tool, the designer must determine rules for placing elements relative to the grid. The simplest and most obvious placement rule is that elements center on grid crossings. Figure 4 shows different position relations forelements on a simple square grid.Grids need not be always unitary; an alternating sequence of dimensional units can be used, toform a tartan or band grid(Figure 5). A tartan grid can be superimposed on a simpler grid that marks the band centerlines. Elements can be restricted to center on the centerline grid, and limited in dimension to stay within the tartan bands [16].

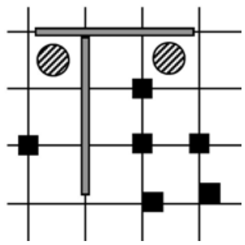

Figure 4. Different element - grid relation

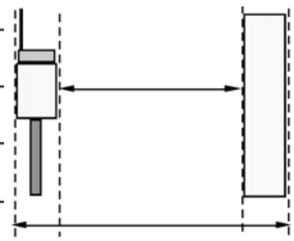

Figure 5. Tartan grids allow for variation in size of built element

Inthe 1970's, Finnish industry developed an open element system called the BES system. The initial wall-slab system was used for housing, then frame-slab system was developed for industrial, commercial and institutional buildings [17]. Similarly, ACC and Solfege Building Systems were developed in France in open building concept as defining of common conventions and modular coordination of building elements on choiced grid. 12x12 feet (~30x30 cm) tartan grid in ACC system and 3x9 feet (~90x270 cm) cm simple grid in Solfege system were used and defined positions of building elements on grids are shown in Figure 6 and 7.

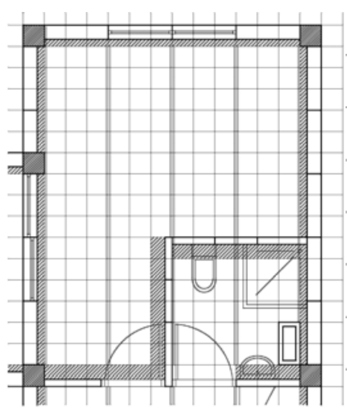

Figure 6. Position of building elements on grid of ACC building system

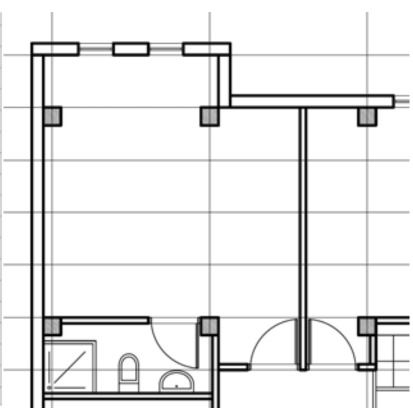

Figure 7. Position of building elements on grid of Solfege building system

Variety grid and positioning of building elements can be defined, but the more practical rules are the better in terms of solving interface problems.

Building Component Design Course

Industrialised building systems are examined in building components design course in Istanbul Arel University by using open building concept. Four different building structural systems are studied and 24 inch (61 cm) grid is accepted for positioning of building elements in terms of being in conformity with each system. Twelve layout types are determined and four building systems are implemented over these layouts in a class including 48 students. So, the differences between each system is more comprehensive for the students and a comparison is made at the end of the course. Cold formed steel frame system (system 1), timber frame system (system 2), prefabricated reinforced concrete system (system 3), and aerated concrete panel system (system 4) are chosen at design education of industrialised building systems, because of preferences at low rise residentials [18]. Cold formed and timber frame system are installed as platform frame system in terms of load distribution [19]. Prefabricated R.C. system is accepted as stick system in terms of sub category. Columns and beams are prefabricated as reinforced concrete elements in conformity with the designed sections and floor and wall elements are consisted of aerated concrete panels. On the other hand, stock ready panels are used at aerated concrete panel system [20]. Scaled models and 3D cad drawings help to understanding of three dimensional design of the systems. Defined common conventions for these four systems are inside the limits of each related specifications and affirmative feedbacks are received at the end of the course. Experiences of building components design course are used during definition of common convetions for design education of cold formed steel framing system.

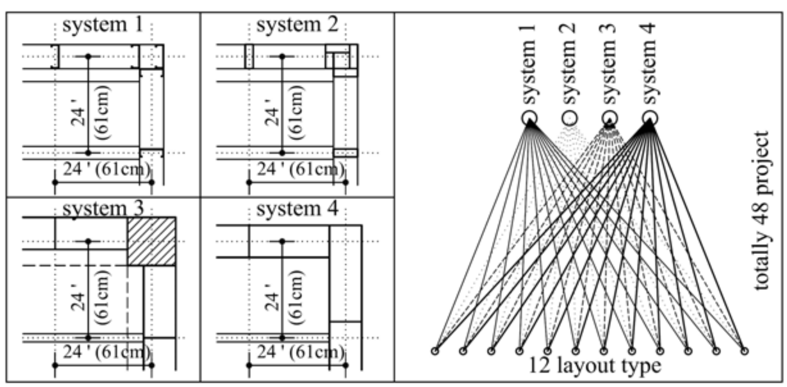

Figure 8. Scope of building components design course

Common Conventions for CFS System Design Education

Common conventions for cold formed steel framing system of which can be used in education field are defined by being in conformity with technological limits of specifications. Catalog datum are shown in Table 1 as in the samples of open building concept; ACC, Solfege and NEN. “Prescriptive method for residential cold formed steel framing” published in 2000 by North American Steel Framing Alliance and “The lightweight steel frame house construction handbook” published in 2005 by Canadian Sheet Steel Building Institute are the bases of this study in terms of technological limits [19] [21]. General provisions are determined herein for the design study apart from details defined in specifications. Definitely, more than limits herein defined in the catalogs can be used in terms of technologically, but this study is narrowed through a basic education model. Proposed education model is basically consisting of support level in terms of open building concept. Three storey samples exist in the world, but, North America’ s specifications limit cold formed steel framing systems as two storey. The proposed system is limited in one or two storey building without basement floor over a reinforced concrete ground floor slab as shown in Figure 9. Positioning of wall studs and floor joists on defined horizontal grid and dimensional coordination on vertical plain are defined in Figure 10.

Table 1. Limits and definition of proposed sytem

Definitions		Attributes	
General	Technical and economical principles	Open building concept	
	Level of decision making process	Support	
	Structural system	Platform frame system	
	Building types applied	One or two storey dwelings	
	Building geometry	Rectengular	
	Modular coordination (basic module)	24 inch	61 cm
	Sub module	12 inch	30,5 cm
	Position of components on grid	on centre	
Wall	Load beraing wall thickness	6 inch	15 cm
	Wall height (stud height)	10 feet	305 cm
	Opening in loadbearing walls (max.)	8 feet	244 cm
Floor	Maximum span for floor joist	16 feet	488 cm
	Height of floor joist	12 inch	30,5 cm
	Floor opening (header span)	8 feet	244 cm
Roof	Roof style	Gable, hip, flat	
	Ceiling joist height	12 inch	30,5 cm
	Roof rafter height	6 inch	15 cm
Misel.	Foundation (Ground floor slab)	Reinforced conrete	
	Stair well dimension	8 x 10 feet	244 x 305 cm
	Cantilever dimension	24 inch	61 cm
	Eaves dimension	24 inch	61 cm
	Non load bearing wall thickness	4 inch	10 cm

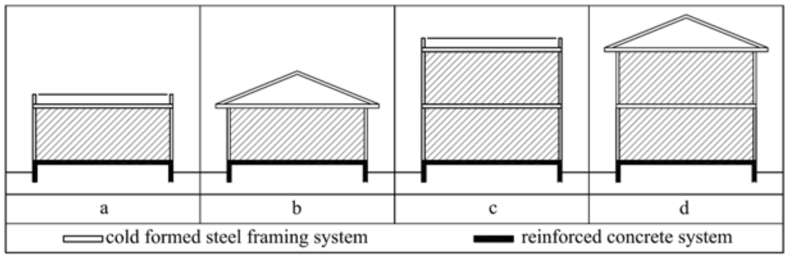

Figure 9. Storey and roof types

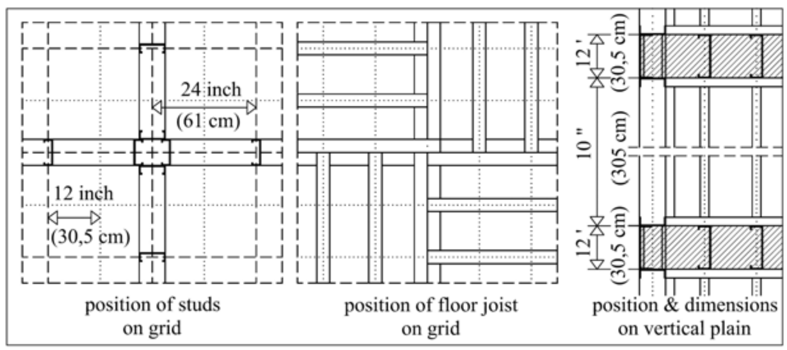

Figure 10. Position of building elements on horizontal grid
and dimensional coordinationon vertical plain

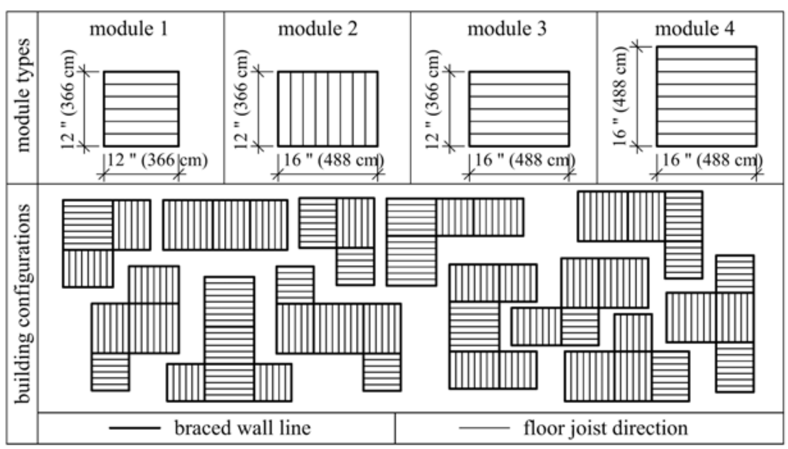

Figure 11. Modules defining braced wall footprint
and building configurations

Right angle is used instead of oblique angle on grid as modular coordination. Four basic modules creating braced wall footprint designed and twelve layout types derive from these four module as shown in Figure 11, since making a comparison and being in conformity with the systems and studied in building components design course. Basic module is accepted as 24 inch (61 cm) and dimensions of modules and building types are the multiplier of this basic module.

Projecting building types having building offset greater than 4 foot (122 cm) are preffered instead of rectengular building type as building configuration in order to make more comprehensive of braced wall implemantation as shown in North America' s specifications.

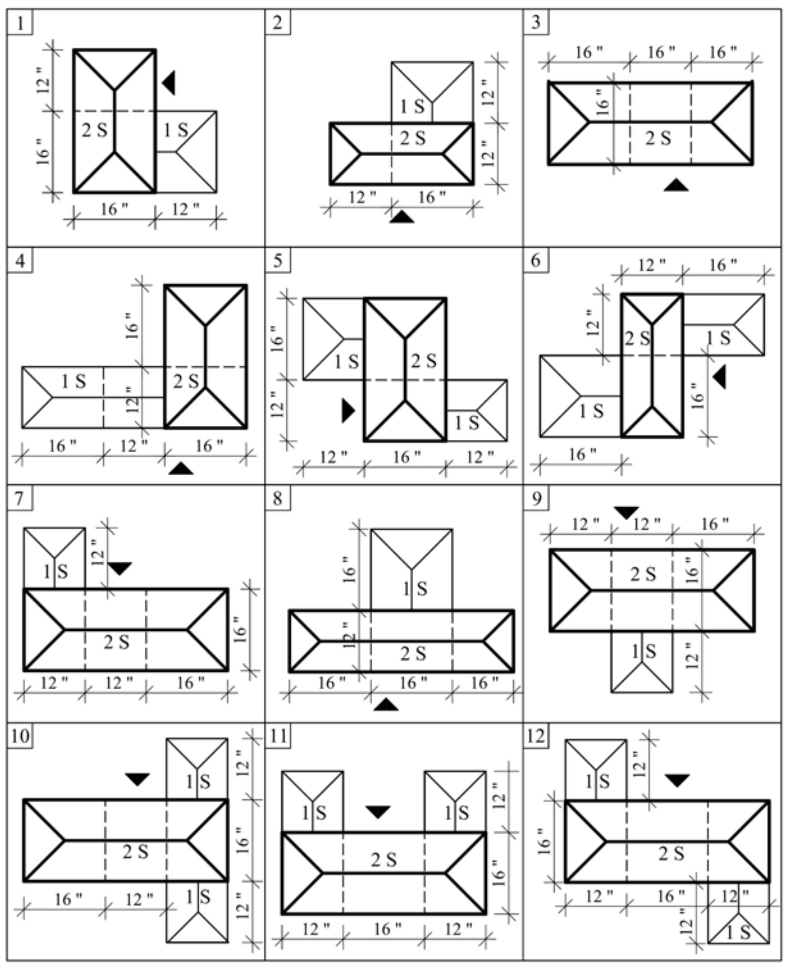

Figure 12. Building types with one and two storey alternatives.

Building types with one and two storey alternatives in Figure 12 will help to understanding of variety wall and floor connections. Floor configuration according to storey alternatives over accepted grid is presented in Figure 13. Single type staircase is preffered in order to supply standardization and 24 inch (61 cm) dimension eaves and cantilever is used as shown in Figure 14. Load bearing wall stud positions on grid is in conformity with specifications (Figure 15).

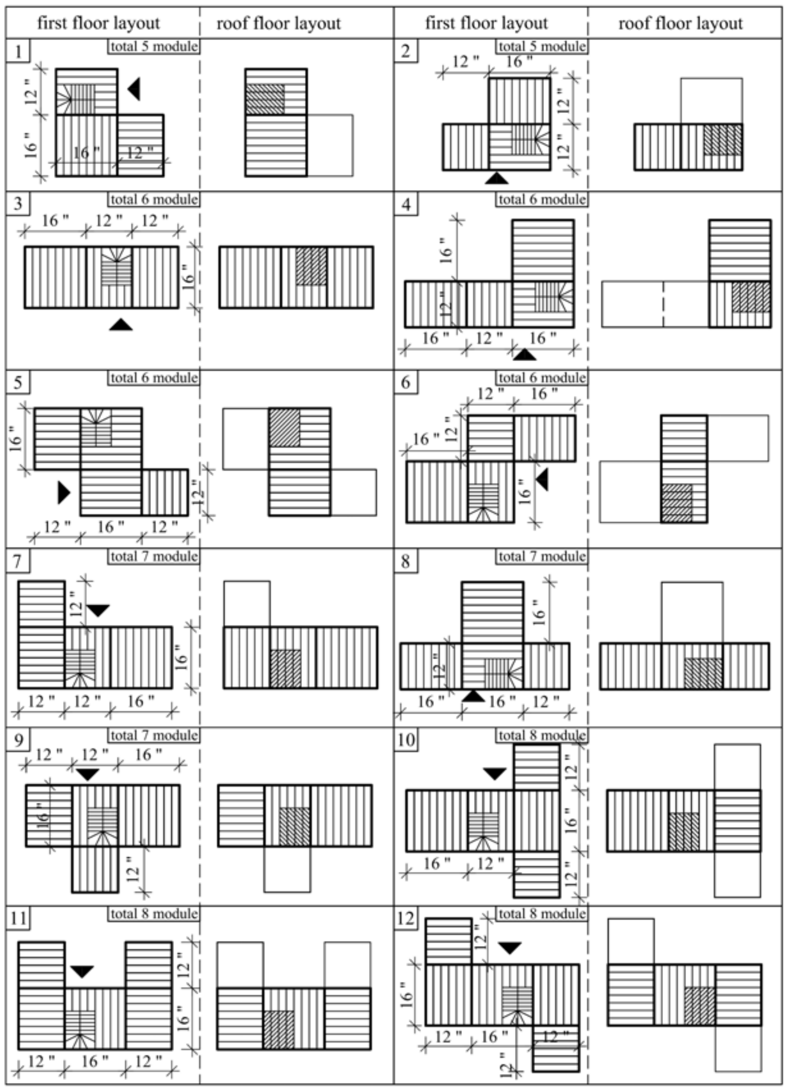

Figure 13. Floor configuration

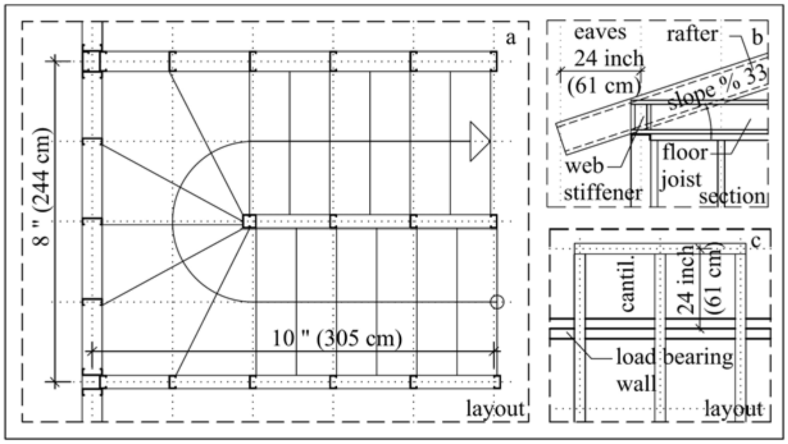

Figure 14. (a) Staircase type, (b) eaves type, (c) cantilever dimension

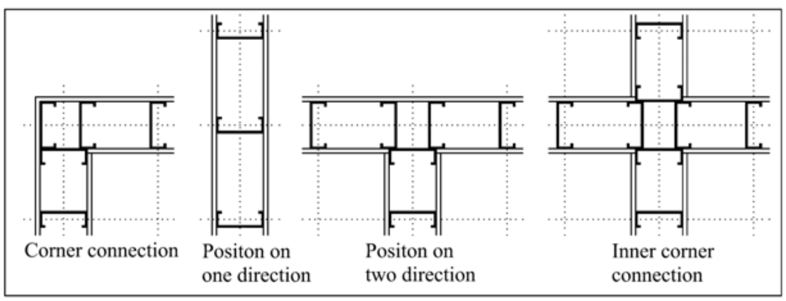

Figure 15. Load bearing wall stud positions on grid

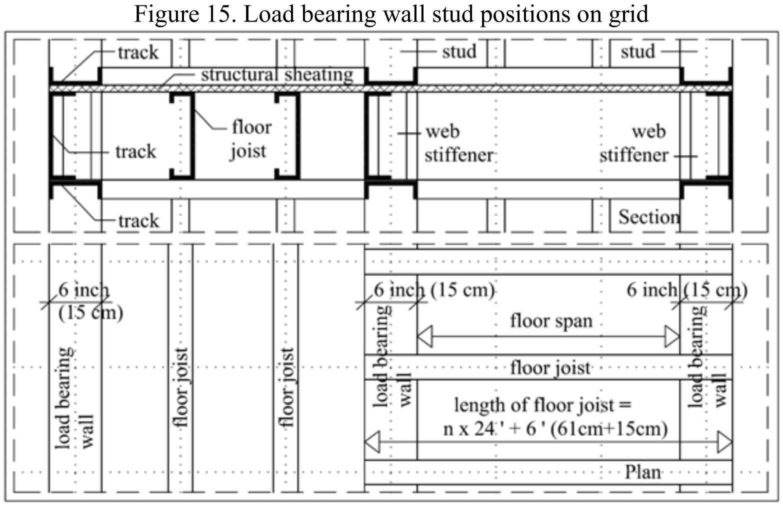

Figure 16. Floor joist positions on grid

Floor joist positions on grid is presented in Figure 16. Variety alternatives exist in terms of building physic that effect positioning of building elements on grid, therefore a typical solution is accepted as shown in figure 17.

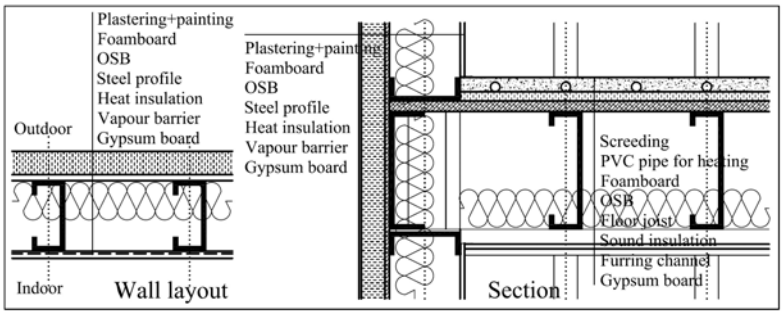

Figure 17. Insulation layers at wall and floor

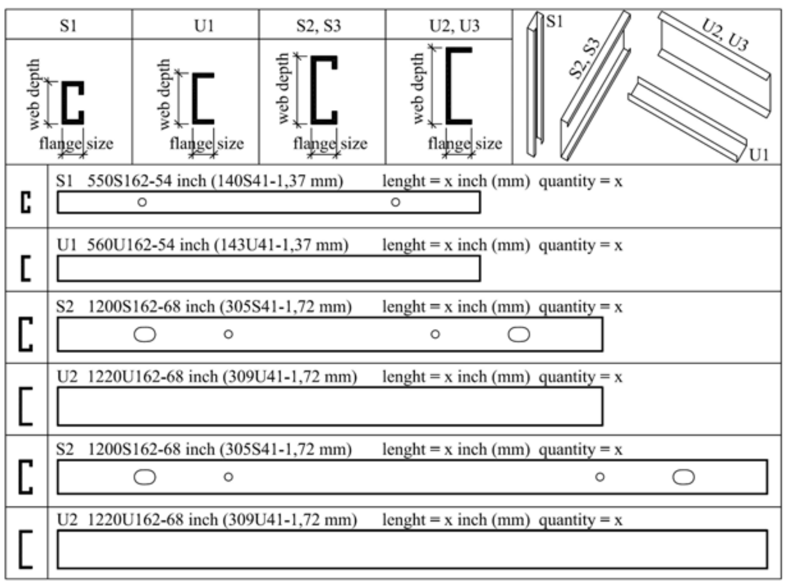

Figure 18. Member types

Using limited number of components over a system catalog (user manual) is a concept used in Meccano and Lego toys and distinguishing of levels of decision making procces in open building concept are the basis of this study. Therefore, member types and numbers are limited in support level so as to enable designing with limited number of members as in open building concept or in Meccano and Lego concept (Figure 18).

Conclusion

Common conventions of which is in conformity with North America' s specifications are defined and catalog datum are presented in this study for the usage of design education of cold formed steel framing system. Designing with limited number of members by using a user manual is the bases of this study. Experinces of toy and furniture industry, such as Lego and İkea concept help to systematization of user manual as common conventions and the study is narrowed through support level in terms of open building concept. Prefabrication principles and open building concept are used in design education of CFS system. NEN, ACC and Solfege building element systems are examined for modular coordination and positioning of building elements on defined grid, so as to enable determine the grid used in this study. Four industrialised building systems as cold formed steel frame system, timber frame system, reinforced concrete prefabricated system and aerated cocnrete panel system are tested by students in building components design course in Istanbul Arel University. 24 inch (61 cm) grid is accepted in term of being in conformity with each system. Feedbacks received from this course is used to design this education model, therefore same grid dimension is used in proposed system.

12 building type can be studied by either single students or groups with two or three students and, so design education of cold formed steel framing system can be conducted with a class of including 24 – 36 students. 3D cad drawings and scaled model studies make more comprehensive of structural installation principles of cold formed steel framing system for students. But, having small dimensions of scaled model members as C and U profiles that is unable to produce by handmade, students got assistance from 3D printing for tiny members which is used in scaled model. This kind of difficulty shows that the requirement of a stock ready tiny members as C and U profiles which can be used in the scaled model of cold formed steel framing system. Proposed education model can be used by undergraduate students of architectural and civil engineering departments and graduate architects and engineers whom interested in CFS system. Increasing education opportunities will help to widespread of cold formed steel framing usage in the countries who have low rate of CFS system production in construction industry like Turkey. Similarly, a national cold formed steel framing system can be designed in the light of open building concept with limited number of members by using a common convention shown on a system catalog in this kind of countries, in order to increase the usage of CFS system. So, manufacturers and designers can seperately contribute to designed system.

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