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SUSTAINABLE BUILDING CONSTRUCTION

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Summary

In many countries building industry uses wood, block, brick, hot rolled steel and concrete for any kind of building construction. But recently it has been recognized that, using these building materials is a big threatening of the global environment. To prevent from that, building specialists started to use Cold Formed Steel (CFS) structure under special building system which is called Light Steel Framing (LSF) in building construction.

From 1990 developed countries started to replace the conventional building material and systems with the new building materials(CFS) and systems(LSF), because of its big advantages of the use of steel in building construction like possibility of reusable, recyclable, economy and the environmentally of material and method of construction. The other advantage of this system is its affect on building construction to change from traditional methods to construct prefabricate and industrial products system as well as act for sustainable and environmental building system.

This paper describes what the sustainable building construction, Cold Formed Steel sections and LSF structure system are, benefits of the use of CFS sections and the LSF building system and how it can be possible to achieve the advantages by using CFS and LSF.

1. Introduction

It is an accepted fact that all human being have a responsibility for the protection of the environment as being the most precious entity for the world of today and for the future generations. Within this context, since the world population grows faster than before, increasing amount of material consumption creates also the problem of increasing waste and increasing pollution. In most countries studies show construction industry can be accepted as one of the important users of material and energy. Building construction due to the demand, ageing of building stock combined with the evolution of requirements of the functions and the qualities of structures, the construction industry is increasingly concerned about large production, renovation, conversion and demolition. In many countries stricter environmental regulations, environmentally friendly and sustainable production and recycling management are becoming more and more a focus in order to reduce adverse environmental impacts from industrial production systems. Especially the minimization and recycling of residues and waste has attracted growing attention in industry in the last decade. It is evident that the construction industry plays a major role in this context.

Indeed, it is quite significant to try to recycle as much construction waste as possible, not only because of the limited dumping capacities but also in order to try to preserve the natural resources. In some countries governments established legislation encourages the prevention of adverse effects such as emissions and waste. In 1997 the Kyoto conference resulted in agreement to reduce greenhouse gas emission by 20% (based on 1990 levels) because of concerns over global warming (Coskun, H 2002). Therefore, it is vitally important to adopt a 'whole life-cycle' approach to design. A life cycle is classically divided in three parts: the product production, its use and its end of life (Figure 1). In other words, the recycling of such materials must be taken into account. Life Cycle Assessment is widely recognized as a method that brings the best results in studying the environmental impacts of products, which is now standardized at the international level thanks to the ISO 14040.

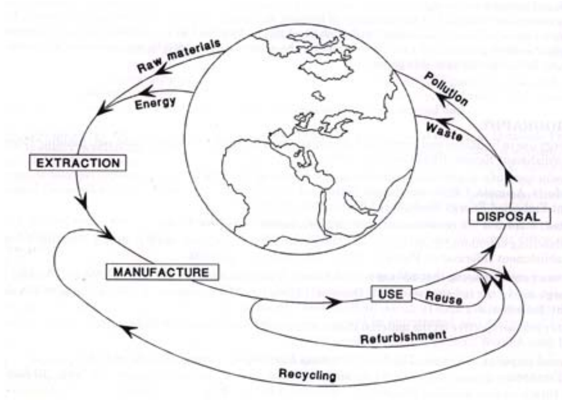

Figure1 The circular environmental economy

One of the most important concerns for all members of the building team is that of sustainability. Also at the start of the new millennium attention is once again focused on sustainable issues. Building has a lot to answer for in terms of the amount of natural resources consumed, the amount of pollution created, the amount of energy wasted and the amount of waste generated. That is why it gains a big importance for this sector to consider energy savings, renewable raw material usage and minimization of the pollution as much as possible. Technologies advances in materials and mass production have given the designer incredible potential in terms of choice (Figure 2)(Emmitt,S 2002). Conversely they also require the designer to have greater knowledge and understanding of materials and technologies.

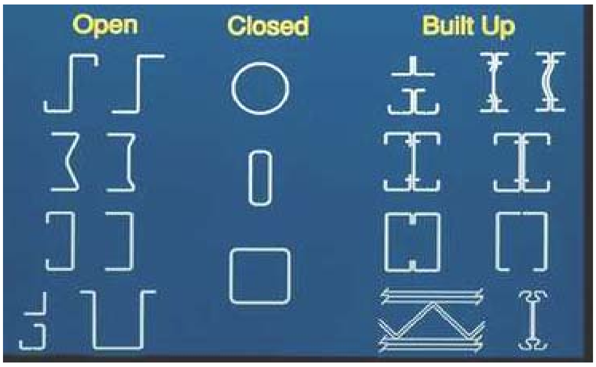

Figure 2 Major types of CFS sections: open sections closed sections and built-up sections

2. Building construction

In developed and developing countries the use of CFS sections (Figure 2) as a suitable for sustainable building material which is basic material for LSF building system started from 1990. LSF building system consist three main building material (galvanized steel, glass wool and gypsum board) and method of construction industrial system. Studies on the history of some developed and developing countries show in different countries different reasons effected to change and choose of building system, materials and sustainability aspects. In this paper the author tries to explain why some methods of building construction going to be popular also discuses about the role of house building in the change of building construction then it shall be mentioned methods of housing construction.

2.1. Residential construction In US

In the US homebuilders have used wood as a building construction material for centuries because of its abundant supply, relatively low cost satisfactory performance, and most of the development can be done on site rather than in a factory (Fallah, M.H. 2001). The traditional method of house building in timber is often referred to as two-by-four (2 x 4). From 1930s, authority because of environmental and economic concerns began to be expressed about using wood for building construction, prompting the building industry to research alternative materials and methods. Figure 3 shows some of the statistics for the use of materials for wall framing in house construction up to 1995. For both interior and exterior walls, timber had 93% of the market with steel only a very small proportion, approximately 6% for interior and as little as 1% for external walls(Fallah, M.H. 2001).

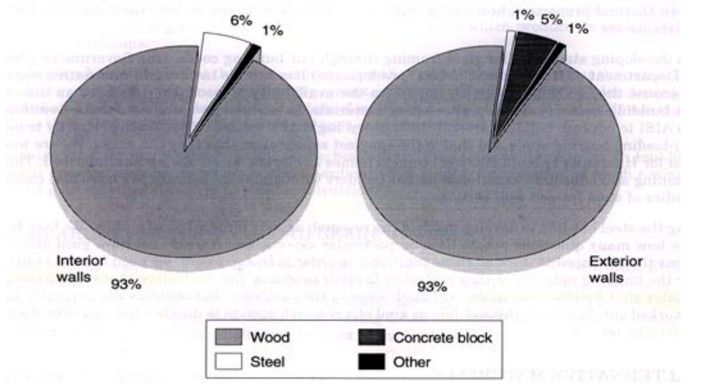

Figure3 Framing materials used in new home

2.1.1 Market share

Studies show the residential construction is an extremely significant part of the overall construction market in the domestic US economy. For example, annual expenditure on construction in 1999 accounted for 7.3% of the GNP or $415 billion. About 40% of this was in the residential sector. Study shows in 1998, approximately 2.1 million residential units were built in the US and Canada (single-family, multi-family and manufactured housing). Since they found CFS was a sustainable building material, they started to replace wooden material with CFS. Studies show in 1992, there were only about 500 homes built in light gauge steel but this number has been grown.

2.2. Residential construction in Japan

Japanese buildings background shows before 1940 most of building in urban areas were built of wood, and were destroyed by fire during the war. According to an estimate to replace all those houses in wood would have required 150 years production of timber. The government therefore devised a new policy for housing construction including a move to prefabrication, the use of non-flammable materials and the preservation of timber resources. However, Japan is one of the most earthquake-prone countries in the world and is also regularly buffeted by typhoons. The advantages of steel framed housing - lightweight, strong and ductile – are therefore particularly relevant. This was emphasized in the extensive import of steel framed housing for temporary dwellings in the reconstruction work following the Great Hanshin Earthquake of January 1995.

2.3. Residential construction in other countries

Australia is a highly urbanized country, with 65% of all of housing being built in major cities. The building construction was principally timber framed, as in America and many European countries. The use of LSF for house construction began in Australia soon after the Second World War. The main driver for LSF housing in Australia was the shortage of building materials.

In Sweden, wood has been the traditional building material used for residential construction, based on well developed timber industries. However, the struggle to maintain the finite natural resources of the forests has become harder. Due to the steadily decreasing average age of the harvested trees, the overall quality of the wood has started to suffer. Therefore, during the 1990s builders began to substitute LSF for timber in the residential sector encouraged by the Swedish Institute of Steel Construction (SBI).

In Korea, bricks and concrete have long been the construction materials of choice and prior to 1996, structural steel sections had never been used in housing structures. Ninety percent of single or two-storey housing were of masonry wall construction, and the rest were timber. Apartment buildings (six to thirty storey) were invariable built of reinforced concrete. In February 1996, POSCO joined forces with other leading local steelmakers, construction firms, and materials manufacturers to found the Steel House Club under the auspices of the Korea Iron and Steel Association to accelerate the adoption of steel framing in Korea's residential construction market.

Current methods of residential building construction in Iran are generally site based, ‘self-build’ and most of them have been built by private sector, so the result of those housing construction is slow, of variable quality and wasteful, and main future of this method of house construction performed poorly in earthquake resistance. This is the case even for more modern methods of construction with new building material, because the workforce has inadequate skills. In Iran house building is the largest part of the building construction sector and 95% of housing was built by the private sector and 70.3% houses ownership.

There is a three tier building industry in Iran: traditional method (floors, roof with steel), skeleton system (RC, steel frames), and industrialized system (RC, steel frames). However, recent census in 1996 shows that 92% of residential building construction in Iran has been built by traditional and skeleton methods. The evaluation of three popular building construction methods in Iran show steel framing is economical compared with the other two systems. Reasons for this were the high speed of construction of steel frames and presence of an established steel construction industry with suitable equipment, plant, skilled workforce, and experience.

Weakness of the connections in conventional building is an important problem, because during earthquakes, the connections are subject to large forces. Unfortunately popular connection details for conventional steel framing in Iran is welding where is used for the majority of steel connections and most welders are not properly trained. The result is that they usually do not comply with what the engineers have specified.

To overcome earthquake need to concern for the choice of forms, methods of connection, and materials should take account. Therefore the public opinion and the related professional groups has started to discuss the alternative building methods and building materials together with the other improvement measures to be considered for the conventional design and building systems in the country.

Studies show reinforced concrete buildings constitute the highest portions of the construction preferences as the traditional way of building system in the Turkey. Natural disaster (earthquake) is also the big problem in this country for the required handling, demolishing and landfill stages of collapsed or irreparable buildings and their material waste after earthquakes. To overcome this problem the considerations of earthquake resistant, flexible, light weight and environment friendly steel building systems also has been concerned by authority in this country(Coskun, H. 2002).

3. The role of steel in sustainable development

Steel construction has a history of more than 100 years in cities for multi-storey building and other applications. Therefore, the reliability, durability, and consistency of steel are therefore well proven. Many of the applications involve shell structures, such as facades and facade components. The use of galvanized and stainless steel has increased considerably and the applications of the material have become more diversified in significant European building projects in the 1990s.

The use of the cold formed steel (CFS) sections started in the UK and US in the 1850s and developed through the use of thin steel sheets for household appliances, car bodies, storage racks and crash barriers. Less than one hundred years after its invention, the properties of stainless steel are being utilized in all building parts, from cladding to load-bearing and supplementary structures.

4. Cold Formed Steel (CFS)

Traditionally steel has the image of a heavy or cumbersome material, particularly compared with timber, but experience of the use of cold formed lightweight steel is just the opposite (Figure 4). Cold-formed sections are lightweight, easy to handle, economic and of high quality, making them suitable as an alternative to traditional timber framing. A thin, flat sheet of steel cannot support much weight, but if it is formed into a corrugated sheet, the folds act as stiffeners, and can increase the strength of the same sheet many times over, because most of the strength and stiffness of the section depends on the shape and not its thickness. An important difference between hot rolled and cold rolled sections is that hot rolled steel is only available in a limited range of standard units, weights and section sizes but for cold formed steel is possible to produce in many vary configuration in cold temperature and in manufacture, which architects can devise their own unique section profiles to suit particular needs (Figure 2).

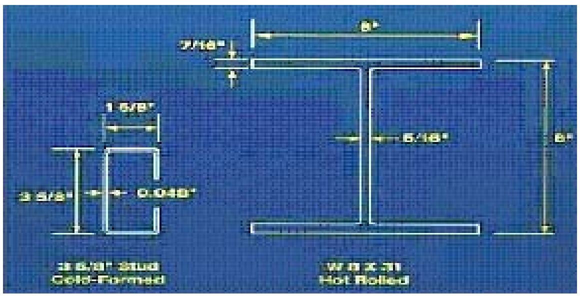

Figure4 Comparing CFS with hot rolled Steel

4.1 How cold-formed sections are used

Traditionally, cold-formed steel sections have been used as secondary structural elements and also primarily in commercial construction. Cold-formed sheet steel panels serve a double function because they can be used as surface as well as structural elements. Their strength, lightweight, versatility, non-combustibility and easy of production has convinced architects, engineers, builders, and manufactures of building products that cold-formed sheet steel can help them provide improved function and greater aesthetic appeal for many application at low cost. The wide variety of shapes and sizes of CFS components offers considerable design flexibility. This can help to optimize the use of steel in a building and hence reduce weight, thereby improving resistance of the building against earthquake. LSF by using CFS sections is the building construction system, which is low in weight and important for poor ground and seismic conditions, because low weight is significant an advantage for construction in such areas.

As a result of this the use of CFS for construction began to develop, but manufacturers faced difficulties due to the lack of an appropriate design specification. In response the American Iron and Steel Institute (AISI) published the first edition of the Light Gauge Steel Design Manual in 1949, based largely on the continuing research sponsored by the Institute at Cornell University under the direction of George Winter. Since 1950 commercial builders involved in the erection of apartments, shopping malls, hospitals, and low-rise office buildings, readily accepted lightweight sections for non-load bearing walls. Although, in tall multi-storey buildings the main framing is typically heavy hot-rolled steel sections and the secondary elements of cold-formed steel members. In the US by the 1960s, although the use of CFS had increased in the commercial sector it had still not been widely accepted for residential construction, because steel framing remained at least twice as expensive as timber construction. Conditions have been changed since the sixties; steel has become cheaper, and the quality of timber has significantly declined[139].

The other significant influence encouraging greater use of CFS has also been fluctuating timber prices for example, in 1992 lumber prices rose from a steady $200 per thousand board foot (tbf) to an historic high of $510 per tbf, and then dropped to around $377 per tbf in 1994. In contrast steel prices remained very stable during this period. A survey about timber, also conducted in 1995, indicated that 59% of builders felt that quality was declining. The reason for this was that the US Government had cut back on timber extraction from old-growth forests; instead they were using new trees, which produce an unstable product with major quality problems. This prompted an increased interest in the use of LSF as an alternative form of construction.

5. Sustainability of steel

Three primary measures to reduce the environmental burden and make sustainable activity are extending the service life of a building; the reuse, or extending the service life, of parts; and the recycling, or extending the service life of materials. The extension of the service life of a building itself, amongst others, is expected to directly contribute to reducing the environmental burden.

Steel comparing with the other buildings material, have lower negative environmental impact concerning the energy use, raw material consumption and created material waste. According to a study the composition of wastes generated within the building life cycle thus obtained is shown in percentages of weight by material and presented in Table 1 (IWATA, M. 2002).

Table 1 Weights by Material

Material	Weight (ton)	Percentage (%)
Concrete (debris)	1970	67.1
Steels	622	21.2
Woods	126	4.3
Aluminum7	7	0.2
Glasses & Ceramics	135	4.6
Metals	23	0.8
Plastics	28	1.0
Oils	16	0.5
Fibers	10	0.3
Total	2937	100.0

According the table 1 the used concrete (debris) which form the floors and walls accounts for over 50% of the total waste, and the steel, for approximately 20%. Therefore, sustainability of steel as the construction material supports its strong position against the other building materials as well. The weight of reused steel members accounts for approximately 70% of the total weight of steels. Promoting steel as the alternative way of building system against wood is also a very positive and effective environmental approach in considering the destruction of trees and thus the scarcity of forests. While it is predicted that the iron ore resources will last 7 million years with today's mining activities; it is not easy to renew the diminished forests especially within a short period of time.

It is also important for our environmental values to note that; the energy need to produce one ton of scrap based steel is about one fifth of the ore-based steel. From life-cycle perspective, materials may have down-cycling property which produces lower grade materials. Actually steel is the only material with a closed material loop which is an important advantage when compared to many down-cycled materials. It can be 100% recycled to the same product, function and quality as before. It is also possible to convert the recycled steel into another metal product easily depending upon the industrial needs and market demands. On the other hand, steel industry is spending a great effort to bring the emission levels much more down the upper limits. When we consider the importance of this fact, it is quite obvious that constructional use of steel offers great advantages concerning the refurbishment and reusability properties.

Therefore, building constructional by CFS presents a lot of positive environmental impacts regarding its sustainability, refurbishment, recyclables and reusability issues. It also presents a lot of advantages in making energy efficient buildings. Additionally, when considering the earthquake resistant, durable and easily reusable or dismantling buildings steel construction becomes a very strong building alternative. It gains a special importance concerning the required structural performance, damaged building reinforcement and waste material management especially in the earthquake areas.

6. Earthquake problem

Earthquakes never kill people, rather it is collapsing buildings which cause death and injury. Obviously this was not a natural outcome but, unfortunately a human failure. In some countries like Iran all parts are prone to earthquake, 77% at high risk, 20% medium and 3% at low risk. Earthquake is a very important natural phenomena causing the structure disasters for many years.These are why this environmental issue must be taken into account when making the preference for building system and building materials for the earthquake risking areas. Regarding these important environmental impacts of construction industry, steel construction can be accepted as a very advantageous construction method. Considering the natural disasters threatening human life by causing structural failures of buildings for many years, earthquake is very important one of this kind of disasters regarding its damages.

Traditionally to control earthquake problem engineers tried to solve that by using extra connection such as stiffness components and bracing in building. However the code of building construction suggested to overcome earthquake problem need to reduce the weight of building, which is needed to consider by designer (architect) rather than engineers. Application of CFS sections in building construction provided this opportunity for designers to use this system to co-operate with engineers to overcome this problem by considering to use low weight building materials and using certain connection.

7. Lightweight Steel Frame (LSF)

Lightweight Steel stud and joist systems, formerly used primarily in commercial construction, are now cutting costs and speeding construction, of single-family dwellings and multi storey building construction (Figure 5). LSF framing for house construction has grown rapidly in the past 10 years in some countries such as the UK, US, Australia and Japan. The system is now competitive with conventional methods, particularly in those countries where speed of construction is important. LSF has got considerable potential, and it offers many advantages such as prefabrication, adaptability, lightweight are relatively simple to produce, and also consisting of just three basic materials: galvanized steel, gypsum board, and mineral wool. This structural system can provide good ductility, indicating good potential performance in earthquake conditions and all of them because of using cold formed steel components.

Figure 5 Multi-story from CFS sections

CFS sections in LSF building system are pre-manufactured and prepared for easy and rapid erection on site. Framing members can be manufactured with pre-punched holes for running piping and electrical wiring. Therefore, provision for service runs within the framing system will therefore reduce construction time and improve finished quality.

Ease assembly of the LSF framing system is another factor which encouraged its popularity in those countries. LSF frame buildings can be assembled using different methods such as individual members, prefabricated components (walls, floors and roof), and prefabricated units comprising walls, floors and roof (modular or volumetric). They are supplied with a galvanized coating to prevent corrosion and have pre-punched holes to simplify mechanical and electrical installations. Because of the method of assembling the system much of the skilled assembly and preparation is done in the factory, the use of skilled labor can be concentrated there. Work on site can then, in general, involve mainly low skilled workers.

7.1. Varity of connection and jointing methods

In any construction system, tools play a major role and can influence which systems are suitable for self-build. The LSF system of construction is characterized by its relative simplicity and the need for only a few essential tools so this presents no obstacle to its use. These included automatic screw guns, self-tapping screws, and abrasive wheel cut-off saws, and thousands of commercial tradesmen became familiar with steel working. The LSF system uses various methods for connections most of which use screws, bolts, or welding, which can be designed to provide good earthquake resistance the system has been promoted in Japan because of proven advantages in earthquake areas.

7.2. Finishing of the building

The LSF system is its suitability for any conventional finishing materials for the external surfaces. Variety of methods of building finish for walls such as brickwork, render, stone and metal; all of these are possible finishes for the LSF system (Figure 6).

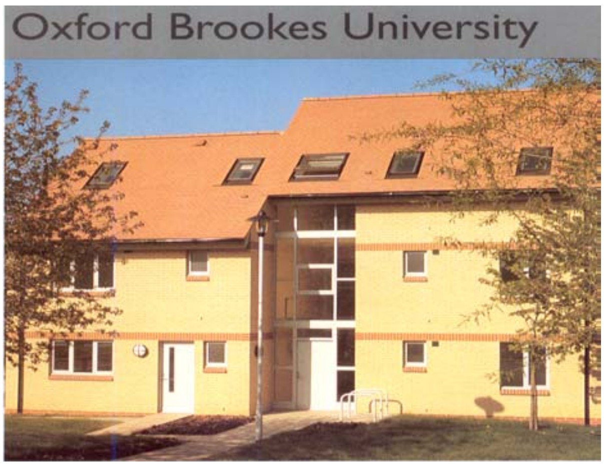

Figure 6 Oxford Brookes University (demonstration of the LSF in a student residence)

7.3. Characteristics of LSF

The building system characteristics would be summarized as follows:

- The light building construction is assembled from cold formed steel profiles. In the gaps between the elements of the frame heat insulation material is placed and the frame is supplied with surface layers made of various materials, forming a layered structure.
- Generally, the elements of the frame structure are constructed of C and U profiles with a dry, assembly style building technology. Numerous steel fasteners, stiffeners and other complementary profiles are connected to the basic elements of the structure.
- The applied materials filling the gaps between the elements of the frame not only perform heat insulation, but also meet acoustical requirements and they are an efficient fire protection tool.

7.4. LSF Association

Some associations are working on application CFS in building construction by providing consultation on testing programs and publications and a meeting schedule allowing members to exchange information and ideas. These members work together to develop standards and design methods, a process that ensures these decisions do not adversely affect manufacturers and can be efficiently executed in the field. Some of them are as follows:

The Light Gauge Steel Engineers Association (LGSEA) was formed in 1994 as a research centre for LSF in the US with the following aims:

a) Resolving technical issues related to CFS;

b) Building a network of engineers able to design houses made with steel efficiently.

The North American Steel Framing Alliance (NASFA) is an organization that was established by the AISI in 1998. The mission of the NASFA is to accelerate the use of light gauge steel framing in residential construction to encourage the widespread, practical and economic use of lightweight steel framing in residential construction

The Institute of Light-Gauge Steel Building (ILGSB) was established in 1955 at the initiative the Kozai Club. Its major objective was to promote the rational application of light-gauge steel shapes in housing construction in particular, and provide design guidance. The use of prefabricated steel, based on CFS sections, for housing quickly gained acceptance, and the Japanese steel industry began to manufacture light-gauge cold-formed steel shapes as a substitute for wooden products.

8. Conclusion

This study shows the building construction is the greatest environmental impact. Steel in building construction compared to the other building materials is very important, because steel construction presents a lot of positive environmental impact regarding its sustainability, refurbishment, recycleability and reusability issues. Steel construction also considering the earthquake resistant, durable and easily reusable or dismantling building becomes a very strong building alternative. Therefore, steel construction like LSF building system which is mostly using CFS can be promoted as a strong alternative building system and building material in global building construction market.

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