Comparison of Steel and Reinforced Concrete as a Sustainable Building Material in Northern Cyprus

Amirhossein Karimizadeh

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Approval of the Institute of Graduate Studies and Research

Prof. Dr. Serhan Çiftçioğlu
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Architecture.

Prof. Dr. Özgür Dinçgürek
Chair, Department of Interior Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Architecture.

Asst. Prof. Dr.Ercan Hoşkara
Supervisor

Examining Committee

1. Assoc. Prof. Dr. Sadiye Müjdem Vural

2. Asst. Prof. Dr. Halil Alibaba

3. Asst. Prof. Dr. Ercan Hoşkara

ABSTRACT

Over the last decades, the use and development of sustainability has become an important issue in all fields, including the construction. Moreover, building materials have always played significant and defining roles in construction value, from the Stone Age to the material world of today. Therefore, the lack of consideration of sustainability in building materials is a serious problem in the construction sector. With regard to Northern Cyprus construction sector, reinforced concrete is generally used to construct buildings structure beams and columns, while alternative structural material like steel is not widely considered.

This research tries to compare sustainability between reinforced concrete as a widely using structural material and steel as an alternative structural building material in Northern Cyprus construction sector. In addition, this study tries to encourage usage of sustainable building materials in building construction sector. Accordingly, the methodology of this study is based on evaluation and comparison between reinforced concrete and steel in context of sustainability features. Additionally, the results of evaluations are analyzed by using a point-based rating system to achieve enhanced comparison.

According to the result of this thesis, steel is a more sustainable structural building material than reinforced concrete. For instance, steel as a recyclable and reusable building material can reduce environmental impacts from construction by reducing the use of raw materials. Also, steel structure is more economical with the added advantages of being constructed faster, lighter and more flexible than reinforced

concrete. However, as mentioned reinforced concrete is a widely used structural building material in the Northern Cyprus construction sector. Hence, all architects and constructors have to be aware and consider the benefits of using sustainable materials in the building construction sector.

Keywords: Sustainability, Building Material, Features of Sustainable Material, Reinforced Concrete, Steel, Northern Cyprus.

ÖZ

Son yıllarda, kullanım ve sürdürülebilirlik gelişimi tüm inşaat alanlarında çok önemli bir konu olmuştur. Daha da ,bunların malzemeleri her zaman çok önemli bir rol üstlenmiştir ve bu da taş çağından bugün maddesel dünya sisteminde inşaat kalitesini belirlemede önemli bir roldür. Bu nedenle yapı malzemelerinin sürdürülebilirliğini dikkate almama eksikliği inşaat sektöründe çok ciddi bir problem teşkil etmiştir. Kuzey Kıbrıs inşaat sektörü göz önünde bulundurduğumuzda , betonarme binalar genellikle yapı kiriş ve kolonları oluşturmak için kullanılırken ,alternatif yapı malzemesi olarak örnek verecek olursak çelik yaygın olarak önemsenmemektedir.

Bu araştırma dengeleri Kuzey Kıbrıs inşaat sektöründe sürdürülebilirlik karşılaştırılabilmesi için yapısal Malzemelerin betonarmede yaygın olarak kullanılmış ve çeliğin alternatif olarak yapı sektöründe kullanıldığı görülmektedir. Buna ek bu çalışma denemeleri bina inşaat sektöründe sürdürülebilir bina malzemelerini teşvik etmek için yapılmıştır. Buna bağlı olarak bu çalışmanın esas aldığı yöntem , betonarme yapıya konsantre olmak ve sürüdürülebilir çelik bağlamındaki özellikleri belirtip tüm bunları değerlendirme ve karşılaştırma. Buna ek olarak Değerlendirme sonuçları analiz edildiğinde geliştirilmiş karşılaştırma elde etmek için nokta – bazlı derecelendirme sistemi kullanıldı.

Bu tezin sonuçlarına göre çelik yapısal inşaat malzemesi olarak betonarme yapı olmaktan daha fazla sürüdürülebilirdir. Buna karşılık çelik geri dönüşümlüdür ve yeniden kullanılabilir inşaat malzemesinin çevresel etkiler düşünülerek inşaata

işlenmemiş ham maddelerin kullanımını azaltır. Bununla birlikte çelik yapı daha ekonomik olarak inşaatın hızlı bitmesinde daha çok avantaj sağlarken betonarme yapıya göre daha hafif ve daha esnektir. Ancak bizim bahsettiğimiz betonarme yapı geniş ölçüde yapısal bina malzemelerinde kuzey kıbrısta inşaat sektöründe kullanılmaktadır. Dolayısıyla tüm mimarlar ve inşaatçılar farkında olmamakla birlikte bina inşaat sektöründe sürdürülebilir malzemelerin kullanımının faydalarını göz önünde bulundurmaktadırlar.

Ana Kelimeler: Sürdürülebilirlik , Inşaat Malzemeleri, Sürdürülebilir Malzeme Özellikleri , Betonarme, Çelik , Kuzey Kıbrıs.

To My Family

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Chapter 1

INTRODUCTION

Nowadays, inquiries show that the construction building sector has a strong impact on human life quality in the different ways like how to use land for building, using natural resources for construction materials, the amount of energy consumed for producing the construction material, and energy use over the construction period (Oktay, 2001). Moreover, the growth in universal population is believed to be from 6.5 billion in 2005 to approximately 9.0 billion in 2040 (see Figure 1). Accordingly, with consider to grow global population, it is clear that the necessity for construction building is also increasing. Therefore, these are the key reasons that helped the concepts of sustainability to become more and more popular during the last decade.

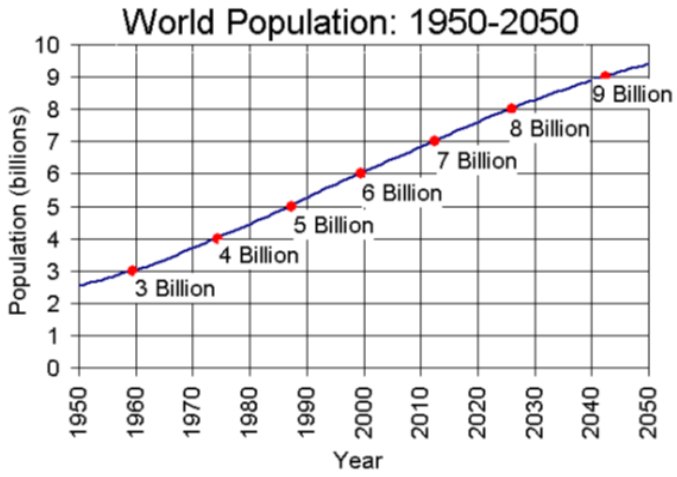


Figure 1. World Population: 1950-2050 (U.S. Census Bureau, 2015).

Sustainability has been widely considered for buildings designers and engineers in construction sector. Furthermore, building materials are playing a considerable role in the building construction industry and it has a strong influence on achieving the sustainability goals. A reasonable selection of materials can help to reduce envıronmental damages, and also improve beneficial economic impacts and social performance in building construction processes (Franzonia, 2011).

To sum up, architects and constructors have to consider sustainability of building materials for success in outcomes and optimal decisions when they select materials. By intelligent awareness to choose reasonable building materials and methods can improve the quality of building construction sector and decrease impact on future generations and promote environment value and also social advantages (Castro-Lacouture et al, 2009). In the part below, former researches, research in the field of sustainability and building materials are taken into account, to benefit from findings of other scholars and implement the results of their research to extend the limits of the available knowledge.

1.1 Literature review

There are several important guidance about the science of building materials and their character in improvement of construction to achieve sustainability. For example, Gordon (1976) considered the evidence of progress in the knowledge of materials science in his book that cover since World War II to approximately 1970. In other hand, Gordon showed the use of knowledge to develop materials. He also points out the importance of realizing materials skill to show the performance of regular materials and show the strong influence of material on building performance also (Gordon, 1976). Relation between construction industry and economic, social and environmental sustainability is important research area in construction sector.

Sustainability has officially settled to be helpful for the improvement of life both for human and planet. Sustainability means how people can make human life more protected with extended economic frameworks perpetual and imposing less effect on ecological frameworks (Oktay, 2001). Overall, the main principles of sustainability are environment, economy and society and also in neighborhood scale, and in various parts like industry, building construction, tourism, and so on (Hoşkara, 2009). Sustainability essentially is prosperity of environmental, economic and social solace for the mankind and satisfaction of their vital fundamental desire to have a superior personal satisfaction throughout today and future without trading off the future generation prosperity for their needs (WCED, 1987).

According to Graham (2009), the building industry is a major consumer of natural resources, and therefore many of the initiatives pursued in order to create ecology sustaining buildings are focusing on increasing the efficiency of resource use. He

stated that the ways in which these efficiencies are sought are varied. Halliday (Halliday, 2010) observe that certain resources are becoming extremely rare and the use of remaining stocks should be treated cautiously. The author called for the substitution of rare material with less rare or renewable materials.

Since the 1980's, the design and construction use more and more high performance materials. (Shi, 2008). Sustainable design and construction, an innovative building approach that incorporates high standards of environmental protection with an emphasis on life-cycle cost considerations, because these substances are more environmentally friendly and possess greater recyclable capability than conventional construction materials. Conserve natural resources and reduce negative impacts on the environment.

Kim and Rigdon (1998) noted that consideration and use sustainable building materials is a considerable approach for architects, constructors and structural engineers to achieve sustainability in building construction sector.

Mostly, sustainable building materials are with low contaminants generated, harm of contaminants free, high recycled, high reused content, and rapid renewable periods. Furthermore, the remarkable and universally acceptable definition of sustainable building materials still does not exist however they are generally considered as environmentally responsible or environmentally friendly building materials (Meisel, 2010).

Cautious selection of construction materials exists the most effortless path for builders to start out integrating sustainable strategy in building constructions.

Generally, cost has been principal thought when looking at comparable materials for similar purpose. Nevertheless, standard cost of building elements characterizes to just the assembling and carrying costs, without any consideration to environmental or social expenses. Sustainable construction is the selection of materials and methods in building constructions that will oblige less utilization of natural resources and expand the reusability of such materials and methods for the same reason (John et al, 2005).

The building materials assume a huge part in building development since it affects the performance of a building and impacts the accomplishment of needed objectives. A proper choice of materials may help diminish the embodied energy in a building, energy utilization, carbon dioxide outflows the environment, environmental influence over the life cycle, energy use in materials creation forms, and air quality uneasiness among others. When selecting materials, designers have to consider many factors for successful consequences and ideal decisions. Factors such as environmental performance, price, safety, mechanical properties and physical properties are often included in the process (Florez & Lacouture, 2013).

Spiegel and Meadows (2010) mentioned that “sustainable building materials are those that use the Earth’s resources in an environmentally responsible way”. They work within the pattern of nature’s cycles and the interrelationships of ecosystems. Sustainable building materials are nontoxic. “They are made from recycled materials and are themselves recyclable”. They are sustainable in the approach that they are manufactured, the approach they are utilized, and the way they are domesticated after use (Spiegel & Meadows, 2010).

Sustainability of building materials strongly depends on local context. Therefore, considerations of region conditions such as geography, climate and economic and social situations are very important issues in sustainability of building materials. (Oktay, 2001).

Holtzhausen (Holtzhausen, 2007) provides an overview of numerous building materials, and also he mentioned that "buildings intended for a long life span should have materials that do not require frequent replacement. A building owner may be willing to pay more in initial capital costs for a building product that requires less maintenance over the life span of the building".

Building materials play an essential part in considering the sustainability of any design alternate. Steel, cast-in-place reinforced concrete and precast concrete each have specific qualities that contribute to achieve sustainability of a project. Suitable sustainable properties are linked with structural elements that have low life-cycle costs, high durability, and high adaptability and contain high-proportions of recycles materials (Naik, 2008).

When evaluating the sustainability of building materials, it is important to consider all life cycle stages. Furthermore, the life cycle stages of building materials can be separated into the following phases (Kim & Rigdon, 1998; Khatib, 2009):

- Extraction of raw materials;
- Manufacturing;
- Construction;
- Use;
- Destruction and recycling or reusing;

According to Douglas (2006) the requirement for maximizing the use of sustainable materials and processes, for example the materials can be reduced environmental impacts, is now well recognized. Material is a key subject of sustainable construction. In other hand, the use of sustainable building materials is a key strategy of sustainable construction. It provides an economic and socially advantageous way of giving otherwise disused buildings a new lease of life (Douglas, 2006).

Kestner, Goupil and Lorenz (2008) provided a sustainability guideline of structural building materials, they conducted a study seeking to which structural building material is the most sustainable: concrete, steel, or wood? They mentioned that this is a general question that many architectures, constructors and structural engineers have either have been questioned by others or questioned themselves. Additionally according to their study, there are two primary challenges architectures, constructors and structural engineers have to consider in evaluating the sustainability of a building material: the first one is identifying the right framework for the material, and second one is comparing the material to others (kestner et al, 2008).

With regard to these literatures it is clear that, sustainable building material is a significant issue that effects directly to the sustainable development, in the building construction industry. By consideration the statements above the connection between building materials and achievement to sustainability within the impacts of sustainable development strategy in building construction industry has been accepted. These references above can be used as a foundation for additional research in order to consider and use of sustainable building materials in building construction sector to achieve sustainability aims in built into the substance of this thesis.

1.2 Statement of the Problem and Significance of the Study

The concept of sustainable materials can be considered as a way to preserve natural resources in construction of a building, which drives the building industry in to more sustainable phase. The consideration of sustainable building materials is a significant issue that is often unconsidered in the building construction sector which relatively can damage the natural resources. Although, as mentioned in the last part, researches showed that building materials play an important role to achieve sustainability in construction building industry. There is no need to mention that using sustainable materials is a valuable new study, and there are too many different ideas in this field. However, consideration of sustainability in building materials context is still in its primary phase in the construction sector. Among many kinds of building's structural materials being used around the world, reinforced concrete is a one of the most common mostly chosen material that has been used in Northern Cyprus for instance but architects and constructors can consider more choices (Celikag & Naimi, 2011). Therefore, there are different strategies that they can use for more structural sustainable materials in Northern Cyprus.

This study could be a point of consideration for architects, constructors and students of architectural fields. Additionally, it can be useful for address other sectors, for instance the public sector, public authorities and research institutes for magnification the position of consideration to sustainability and using sustainable building materials as an important way to be considered in building construction.

1.3 Aim of the Study, Research Question

By considering the mentioned problem, the main aim of this study is to compare sustainability between reinforced concrete as a widely used structural material and steel as an alternative structural building material in Northern Cyprus construction sector to find out which one is more sustainable to use as a structural building material in terms of material usage in building beams and columns structure.

Therefore, to achieve this goal, the evaluations of this thesis should be in context of sustainability principals with regard to Northern Cyprus conditions. Moreover, each country or region has specific conditions; therefore, this study is also focused at highlighting the problems in construction sector, proposing potential answers to the problems and seeking to use of alternative construction material in construction sector. Finally, encouraging the usage of sustainable building materials in Northern Cyprus is another aim, Architecture and constructors should consider to sustainable material in the construction sector to improve the quality of life for residents and cut down the usage of unsustainable building materials.

The study will answer this main question; which structural building materials (Reinforced concrete or Steel) are more sustainable by consideration to Northern Cyprus conditions? To achieve this fundamental question, other sub questions had to be considered: What is sustainability? What are sustainability aspects? What are sustainable building materials? What are features of sustainability in building materials? How we can measure sustainability of materials? What are the Northern Cyprus construction sector conditions? All the above questions will be covered in the framework of this thesis.

1.4 Methodology of the Study

In this study complex methods were used to make a comparative study that evaluations the sustainability of reinforced concrete and steel in terms of materials usage in columns and beams of the building structure. The methodology of this study is based on evaluations and comparisons between reinforced concrete and steel as structural building materials in context of some of the main important features of sustainability. By consideration to these methods, the features of sustainability that considered in this study came from usage of existing knowledge.

Furthermore, the methods of data collection are based on complex methods of in-depth personal observation and related existing knowledge. In addition, in this thesis result of evaluations are analyzed by a point-based rating system to achieve an enhanced comparison between reinforced concrete and steel. Furthermore, the rating system is divided into three levels that include: low, medium and high level.

Likewise, the features that considered in this comparison of sustainability cover all sustainability aspects, such as environmental, economic and social aspects. Because of, in any rating systems or methods to measure sustainability, consideration to all sustainability aspects supports true sustainability. In other hand, the most effective method for measurement of sustainability in building construction sector is attention to features of all sustainability accepts (Pitt Matthew et al, 2009).

1.5 Limitation of the Study

This study is limited to the sustainability evaluation framework of reinforced concrete and steel material for columns and beams of the building structure in Northern Cyprus building construction sector. Therefore, thesis limitation bases on evaluation and comparison between reinforced concrete and steel to construct building structure beams and columns in context of sustainability.

Chapter 2

THEORETICAL BACKGROUND

2.1 Framed Structure System

The framed structure consists of nets of collected elements. Building construction is complete when the places between the spaced frame members are complete as required. A few examples can be animal skeletons. This kind of building structure is normally easily adapted in terms of differences in shape, dissymmetry of layouts, and the amount of load they carry. Construction can be done in various materials like steel, wood or concrete and variety of scale is possible. Frames are those types of columns and beams tied-together structures which bear and resist both vertical and horizontal forces simultaneously. Structural and covered parts are separated in frame systems (see Figure 4). Ceilings and walls can be covered with other building materials as to wish for the design. In addition, frame systems are more economic and lighter compared to masonry structural system (Ambrose & Tripeny, 2011).

Reinforced concrete frames take longer to build because they are built with the help of formworks. Moreover, this process may be harmful for the standing building. Nevertheless, steel as a structural material is known flexible and lighter. Furthermore, since it is easily to construct and demolish. The below part discusses the considerations of the basic structural elements like beams and columns as the building elements structural systems which are upgraded from. Therefore, column and beam are the two basic elements of this system:

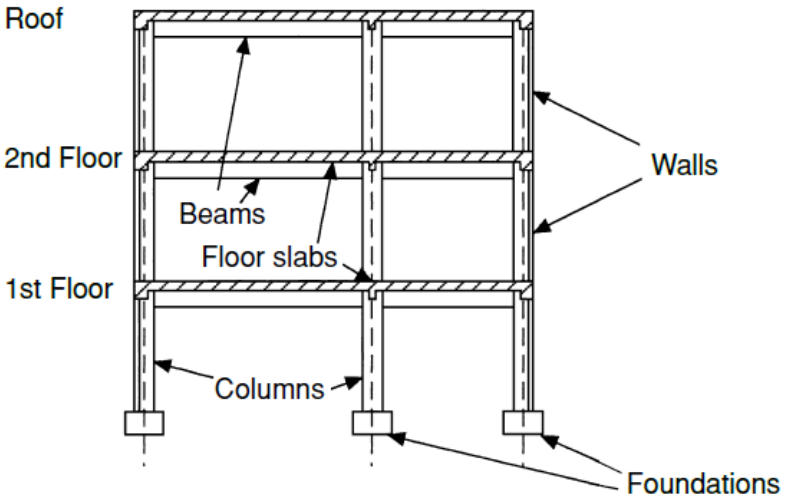


Figure 2. Framed building structure and some elements (Arya, 2009)

2.1.1 Beam Structure Element

Beam is defined as a component which is fundamentally a linear element to transmit loads should be develop internal resistance to cutting, bending and also deflection resistance. What is more, the common name for a structural item which is consumed for stands lateral (vertical) loading, covering and improves internal resisting force activities of shear and bending is a beam. A beam is a structural component that is adept of resisting load primarily because it can resist bending. In addition, the bending force made into the beam material as an effect of the specific weight, exterior loads, span and exterior responses to these loads is known as a bending moment. Structural beams are categorized by their length, material and profile (Ambrose & Tripeny, 2011).

2.1.2 Column Structure Element

Column can be defined as a basically a linear density element. It can be said that column is the structure element that most commonly utilized in building construction. In addition, these vertical components are to bear compressive pressure. It is good to mention that in architecture and structural engineering column is a

structural component that transfers the weight of the structural components above to other structural components below through compression. In another word, a column is a compression element. Columns are typically linear vertical components used for supporting loads which are focused, or when a requirement for open space prevents the usage of bearing walls (Arya, 2009).

2.1.3 Slab Structure Element

The slab is common structural element in modern buildings. Slab components define the sections that make up a slab. Mostly slabs are used to construct building floor systems in building construction sector. Reinforced concrete slabs are used to form a variety of elements in building structures such as floors, roofs, and some types of walls. Slabs can be classified by their materials, span and thickness. Slabs may be solid, ribbed, precast or cast in place. However, all these methods have drawbacks, and research effort has therefore been directed at finding alternative solutions. For instance, a major drawback of precast concrete slabs is that the precast units are heavy and carnage may prove difficult. And also cast in place method can be increased the worktime and human mistakes (Arya, 2009).

One way to construct slabs is usage of a composite system. In this case the steel and concrete interact, with the steel performing the task usually fulfilled by the bottom reinforcement in the spanning concrete slab (Ambrose & Tripeny, 2011). This increases both the strength and stiff nesses of the beams, thereby allowing significant reductions in construction depth and weight of steel beams to be achieved. And also composite construction can be reduced frame loadings. Even more time can be saved if the floor slabs are cast on permanent steel formwork, which acts first as a working platform and then as bottom reinforcement for the slab (Johnson, 2008).

2.2 Structural Building Materials

All kinds of material such as solid, liquid and gaseous have some their specific structural nature. The breathing air has a structure also: It resists density when contained also a car people sit in and drive is an air-supported structure. These available structural materials are brought in use in the design of building structures and the products shaped from them (Ambrose & Tripeny, 2011). This section discusses reinforced concrete and steel as common structural materials and their properties.

2.2.1 Reinforced Concrete

Reinforced concrete is one of the main building materials utilized in structural design. As a complex material, it consists of steel reinforcing bars fixed in concrete. As clear as it is, the three fundamental elements of simple structural concrete are cement, water and a big volume of moveable aggregate (sand and gravel). Concrete is somehow considered a complex material, and its use ties with many concerns, such as finishing, shaping, curing and reinforcing of the cast material. Normal cementations concrete has some features, most importantly its resistance to wetness, insects, fire, rot and wear and also its low majority cost. Being shapeless in its original mixed situation, it can be made kind of forms (Arya, 2009).

Frequently, reinforcements (rebar) and additives are comprised in the combination to achieve the wanted physical properties of the finished material. Concrete is described to be a simple and unassuming material, almost has history for 2000 years in building construction sector. In contrast, reinforced concrete has a generally short history and is truly an alternate kind of building material. Reinforced concrete is a regularly utilized material in building structure part, mainly to construct a various range of

buildings components like beams, columns, slabs, foundations, footings, walls, etc (Ambrose & Tripeny, 2011).

Figure 3. Reinforced concrete structure with beams and columns (URL 1)

Likewise, with the technical improvements in the framework industry the concrete can be brought in use in the making of the very multifaceted forms and this will be advancing gradually with the new skills put in framework industry. Consequently in the future disadvantages of using concrete will solve through addition additives in with the skill. In addition, Reinforced concrete is a kind of building material, which is weak in tension and strong in compression. For reinforcement the tensile power of concrete, constructors decided to use steel inside of the concrete. Therefore, the mixture of reinforce concrete and steel in order to supply powerful bonds has been recognized as Reinforced Concrete. Currently, reinforced concrete is commonly used for the construction of floors slab, beams and columns, as it allows a thinner slab and fewer reinforced concrete to be used to reach the similar reliability and power with regard to unreinforced concrete. Hence, it has a comparatively high compressive

power, durability with compare to steel high fire resistance in general, reinforced concrete can be classified as a high durable building material (Ambrose & Tripeny, 2011).

In general, Concrete has been in use as a building material for millenaries and is used today worldwide as a basic building material. Its winning building properties contain high compressive strength, durability and resistance to decline, workability and worldwide availability and ability to form different forms and sizes (Kestner et al, 2010).

2.2.2 Steel

Steel is used in a variety of forms in nearly every building. It is also one of the strongest, generally the most reliable in its quality control. Steel necessitates the mining of limestone, magnesium, iron ore, coal and other trace essentials. The usage of steel as one of the main structural building material in the constructions in the late nineteenth century for the reason that low-cost approaches used for construction it on a huge scale were industrialized. Steel such as a member of metals family, which has design flexibility, and sensible cost with compare to reinforced concrete (Ambrose & Tripeny, 2011). . However, Steel is the most recyclable material in the world. It can be recycled over and over again without losing its properties, saving natural resources and reducing construction waste in landfills, thus minimizing two major problems faced by the construction sector. And also, steel construction is classified in the dry construction method, therefore it can be reduced pollution in during its construction period (Simões da Silva et al, 2012).

The list below provides some of the main advantages of steel as a structural building material (Simões da Silva et al, 2012):

- Steel structures are quite quick to be constructed which usually outcomes in faster economic payment.
- Steel has a big strength/weight ratio. Thus, the weight of steel structure is reasonably low.
- The properties of steel can be predicted quite confidently.
- There is minimum construction concerns and worker mistakes in the steel construction. The prefabrication of steel structural material delivers a safer, reduces the pollution and cleaner working on the building construction site.
- They are easy to repair and there is easy access to damaged parts to repair them if necessary. These structures can be repaired easily and speedily.
- Adaptation of manufactured. Steel is more flexible in context of architecture approach in comparison with other materials. Prefabricated and mass production of steel is extremely suitable.
- Steel is a greatly recyclable building material. Likewise it is reusable after being taken down from a previous building structure.
- In the steel construction style, frame components are transported in time for installation which minimizes the area required for storage and therefore contributing to an effective construction site.
- Prefabrication ensures correct dimensions and simplicity of erection; wasted material during construction is minimal and most of it is recyclable.

Figure 4.The steel building structure with beams and columns (URL 2)

And also the next may considered as disadvantages of steel:

Two main negative points of steel material for building construction are underlying in the basic building material. These are quick heat gain and resulting loss of strength when exposed to fire and its corrosion when exposed to wetness and air or to corrosive situations. Variability of methods can be used to overcome these limits, two usual ones being special coverings and the encasing of the steel in building construction of a protecting (Ambrose & Tripeny, 2011).

2.3 Sustainability

Sustainability necessitates resources to be saved, the environment to be safe, and also a healthy situation to be kept. By considering to a viewpoint, sustainability is a sign from pure necessities in our life , such as the water which we drink, the air to breathe, come from are essential to our survival and the soils that our food grow on consequently, the human existence is importantly key role to sustain the conditions human depends on. One of the main targets of sustainability is to preserve resources for future generations and doing some preventive measures to keep it healthy. Hence,

with this consideration the concept of sustainability is extremely intelligible but the term of sustainability dose still complex therefore it is difficult to catch exactly the term of sustainability, also an acceptable definition for sustainability has not existed yet (Kibert, 1994).

As mentioned before, the expression of sustainability has proved itself to be beneficial for humane society and natural resources also. In addition, sustainability is a debate of how people can create their life better by economic methods long-term and without negative influence on environmental structures. Therefore, in this consideration it marks the dialog with more meaning to provide unlike meanings besides understandings of sustainability. In other words, sustainability mentioned to as the potentiality of an ecology, society or any such on-going system to drive on effective into the unknown future without being forced into fall and failure by the fatigue or overloading of main resources on which that system depends (Bekir, 2006). Finally, the most popular definition of sustainability is that from the World Commission on Environment and Development (1987) that mentioned; Sustainable development is progress that mention the necessities of the present without cooperating the capability of future groups to meet their own necessities.

2.4 Sustainable Development

Sustainable development is apparent as a compromise between, environmental, economic and social aims. This allows humanity to ensure the welfare of present and future generations without harming the environment and endangering the potentiality of future generations to meet their own requirements. In other words, according to Azapagic and Perdan (2011); “Sustainable development is about ensuring a better

quality of life for everyone, now and for generations to come" (Azapagic & Perdan, 2011).

Furthermore, the point of sustainable development is not constrained to the conventional usage, for example, reusing and cleaning up to ensure environment and planting trees. It likewise manages the advancement and support of the economy to reach a healthy society. In addition, a current study on sustainable development, attempted through the UK authorities, for instance, with regard this issue they mentioned that; "we must rethink how we do this in the future to ensure that everyone can benefit from a better quality of life today and in the future" (Afshar, 2009).

Three pillars that are playing significant roles in sustainable development are environmental, economic, and social dimensions, as shown in Figure 2.

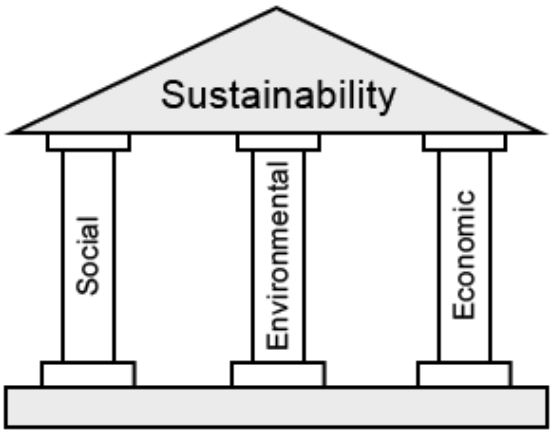


Figure 5. The three dimensions of sustainability (URL 3)

As Figure 3 displays, the economy totally exists inside of the social order, for the reason that all parts of the human economy oblige communication among the people. Society, thusly, exists totally inside of the environment.

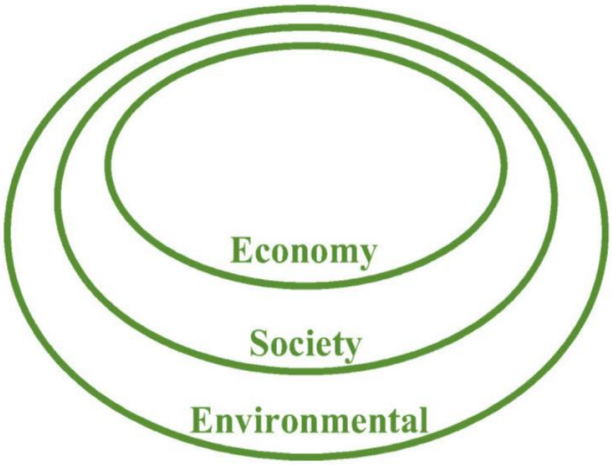


Figure 3. Three principals of Sustainable Development (Holdren et al, 1995)

Overall, sustainable development is the blend of improved socio-economic progress and development, and enhanced natural insurance and pollution counteractive action. Sustainable development upholds the intricate target of giving equivalent accentuation on developing the economic and social aspects while handling the earth environmental resources. It can be comprehended from the above definitions that sustainable development has three aspects: environmental execution, an economic objective, and social viewpoints. Therefore as to achieve sustainable development, each of the three interdependent dimensions must be considered (Holdren et al, 1995).

To complete of this part, sustainability is the capability to continue a defined behavior forever. For more useful detail; according to Spiegel and Meadows (2010) "**environmental sustainability** is maintenance of ecosystem components and functions for future generations" (Spiegel & Meadows, 2010). Additionally environmental sustainability is the capacity of nature to support a characterized level of ecological quality and common asset extraction rates forever. Also, **economic sustainability** is the capacity to provision a characterized level of economic

fabrication forever. Finally, **social sustainability** is the capacity of a social framework, for example, a nation, to function at a characterized level of social well-being forever (Moldan et al, 2012).

2.5 Sustainable Construction

The phrases green, high performance and sustainable construction are frequently used interchangeably; but, the term sustainable construction furthermost widely discourses the ecological, economic and social issues of a building with regard to its community. The Conseil International du Bâtiment (CIB) (1994), a global construction investigation networking group, defined sustainable construction as "creating and operating a healthy built environment based on resource efficiency and ecological design". Moreover, the CIB characterized some principles of sustainable building construction, which would preferably inform choice making throughout each stage of construction process, that continuing during the building's whole life cycle (see Table 1).

Table 1. Principles of sustainable construction (Kibert, 2012)

Reduce resource consumption
Reuse resources
Use recyclable resources
Protect nature
Eliminate toxics
Apply life-cycle costing
Focus on quality of life

Furthermore, these principles of sustainable construction (see Table 1) consider through the whole life cycle of construction, from organization to demolition.

Additionally, the principles put on to the resources required to create and control the built environment throughout its whole life cycle: land, energy, water, materials and ecosystems (Kibert, 2012).

Sustainable construction discusses to the acceptance of building plans, construction methods and materials that are more environmentally friendly, reduction construction cost and social benefits. It additionally means utilizing materials and assets that have sustainable supplies and are promptly accessible from numerous sources. For example, through sustainable construction, we will do our own part to enhance the utilization of regular assets by means of reusing and recycling of materials. This will likewise diminish our dependence on raw building materials (Kibert & Bosch, 1998). Consequently, Sustainable construction provides an ethical and practical response to issues of environmental impact and resource consumption (Kibert, 2012). Therefore, it shows that building materials are playing significant role to achieve sustainability in building construction.

2.6 Sustainable Building Materials and Their Features

The consideration of sustainability in building materials to achieve a sustainable building project has generally been the most difficult and challenging task facing the project team. Spiegel and Meadows (2010) defined sustainable building materials as "those that use the Earth's resources in an environmentally responsible way". At contemporary, but, there is no clear agreement about the criteria for materials that would describe them as sustainable preferable, sustainable responsible, or sustainability (Kibert, 2012).

Sustainable building materials refer to basic materials that may be the components of products or used in a stand-alone manner in a building. Sustainable building materials have low environmental impacts compared to the alternatives. Generally, the significant way to identify sustainable building material is to evaluate them by their quality and characteristics in context of the principles and methodologies of sustainable construction (Kibert, 2012). Therefore, sustainable building materials can be defined as materials with overall superior performance in terms of specified criteria.

The majority of building owners, designers, engineers, contractors, manufacturers, and building officials are not receptive to using sustainable materials to accomplish the task. The unfortunate perception is that sustainable building materials look bad, cost a lot, and do not perform well. Understanding this perspective is essential for effectively resolving such concerns. Therefore, in order to better understand what sustainable building materials are, we need to clarify what are their features. We need to get rid of the pervasive misperceptions about sustainable building materials (Spiegel & Meadows, 2010). Therefore, consideration to features of sustainable building materials is a significant way to achieve understanding of sustainability in building materials.

As mentioned, building material plays a key role in growing the sustainability of building construction sector therefore, there has been much research about this. For instance, Kestner, Goupil and Lorenz (2010) and also Kim and Rigdon (1998) noted that sustainable materials in building construction section: are themselves recyclable, regard the renewability, toxic and effort inside the form of natural cycles

and between connections of environments, have economic benefits. They are sustainable in the ways that they are manufactured, the way they are used, and the way they are reclaimed after use. Furthermore, the below parts are some of the most significant features of sustainable building material according to Kestner, Goupil and Lorenz (2010) and also Kim and Rigdon (1998) that evaluations of this study are based on them. Accordingly, they recognized many features that most of them considered on the material life cycle;

2.6.1 Recyclability

Recyclability measures a material's capacity to be used as a resource in the creation of new products. Steel is known as a frequently recycled material, in expansive character for the reason that it can be simply broken down of waste of construction. When construction experts cannot reuse several of building materials however they can be separated to recyclable elements. Regularly, it is the trouble of isolating rubble from destruction that keeps more materials of making up recycled. Concrete, dissimilar steel, cannot be re-framed once fixed, however it can be ground up and utilized as total as a part of new concrete. Currently, almost no concrete from site destruction is recycled for the reason that trouble in dividing this material from construction debris. Furthermore, plastics are easy for recycling however are frequently combined into different elements which creates division unbearable or hard (Kim & Rigdon, 1998). Generally, reachability has considerable benefit, for instance; through recycling of building materials, the embodied energy can be decreased. Additionally, the energy utilized as a part of the recycling technique for majority of building materials is faraway fewer than the energy utilized as a part of the first production. For instance, aluminum can be recycled for 10–20% of the energy needed to change rare ore into completed merchandise (Kestner et al, 2010).

2.6.2 Embodied Energy

With regard to building materials, the embodied energy of a building material mentions to the full energy needed to create that material, including the gathering of crude materials. Embodied energy contains the energy of the petroleum used to strengthen the gathering or mining tools, the preparing equipment, and the transferal strategies that transfer raw material to treating facilities (Kibert, 2012). This energy is often caused by burning fossil fuels as non-renewable resource. The burning of fossil fuels additionally has serious ecological outcomes, from the local smog to acid rain. Formal building materials by great embodied energy feature can frequently be changed by a building material by low saved energy, when utilizing formal design and construction methods (Spiegel & Meadows, 2010).

2.6.3 Reusability

Reusability is related to the durability and stage of a material. Extremely durable materials may have several useful years of service left when the building in which they are connected is decommissioned, and may be simply extricated and reinstalled in another position. For example, timber from old barns has get to be popular as a recovered material for new construction. Also, reusable building materials are utilized as a part of the redesign of old buildings and in addition in new construction (Kim & Rigdon, 1998).

2.6.4 Reducing the Waste Measures

The waste decline feature directs that the constructer has taken steps to create the manufacture process well-organized, through reducing the volume of building scrap material that outcomes. Furthermore, this scrap can derived of the several forming, decoration, and also final procedures, or from faulty also injured produces. Moreover, products by this characteristic might integrate scrap material or also

removed them for recycling somewhere else. Decreasing waste in the construction process growths the source sufficiency of building materials. For example, concrete can include fly ash from smelting actions. Minimum construction waste during the construction process reduces the requirement for landfill space furthermore gives cost efficiency. For instance, concrete has customarily been premixed by water and conveyed to the construction location. In addition, an extra of material is frequently requested, to avoid delays must a novel transportation be required. Also, this extra is typically disposed of in an on-site or landfill (Kim & Rigdon, 1998).

2.6.5 Use of Natural Materials

Natural material is normally lower in toxicity and embodied energy than artificial building materials. They need less processing and are fewer harmful to the environment. Also, most of them like wood, are theoretically renewable. When natural building materials are combined into building products, the products get more sustainable (Kim & Rigdon, 1998).

2.6.6 Local Materials

Consumption of the local materials reduces transportation distances, therefore decreasing air pollution manufactured through vehicles. Frequently, local building material is improved fit to climatic situation, besides these procurements care zone economic system. However, it is not at all times suitable to usage locally accessible materials, however if materials have to import, they must be utilized selectively and in as minor a volume as possible. Such as, the ornamental usage of marble extracted midway everywhere is not considered as a sustainable selection (Kestner et al, 2010).

2.6.7 Reduce Life-cycle Construction Cost

Construction customers are requesting assurance of their building long-standing economic execution and costs. Likewise, the construction development network of

creators, suppliers, constructers, construction groups are under expanding pressure from customers to minimize whole cost and consider the amount of a building will charge over its life-cycle and exactly how effectively it will keep to meet occupiers necessities (Kibert, 2012).

There is substantial evidence to recommend that numerous establishments, in cooperation the isolated and open parts, make selections about building connected speculation in the first construction cost estimates, with no attention for costs connecting to action and repairs through the lifecycle of the building. A building economic process must be considered through the construction phase furthermore with regard to its conservation and maintenance all by its valuable life. Also, this necessity may be surveyed by utilizing Life-Cycle Cost (LCC) investigative systems. Although sustainable materials may be more expensive at the first, but they always make economic sense on a life-cycle costing (LCC) foundation (Sarja, 2003).

2.6.8 Durability

Long life materials respect to different materials that considered for the similar reason should be supplanted less regularly. This decreases natural resources needs for developed and the volume of cost spent on fixing and the related work. Durable building materials that need less continuous replacement, will require less raw materials besides deliver less landfill unwanted on the lifetime of the building. The lasting of materials is a significant issue in investigating a construction life-cycle expenses. Durable building materials will, more than a building effective life, and also it refers to be more economical than materials that require to be changed more frequently (Kim & Rigdon, 1998; Kestner et al, 2010).

2.6.9 Preventing the Pollution Measures in Construction

Pollution deterrence measures taken in the construction procedure can donate importantly to environmental sustainability. Equal building materials can be constructed by numerous constructors utilizing different procedures. Choosing materials produced by environmentally answerable corporations encourages their attempts at pollution prevention. By be awareness of which producers utilize environmentally sustainable construction approaches, determining their produces, and evading goods manufactured by extremely polluting approaches, engineers can encourage the promotion usage of sustainable building materials (Kim & Rigdon, 1998).

2.6.10 Healthy Materials

All architectures and building constructors should be aware of building materials responsibility for the human health impacts of their operations. Negative human health effects can result from exposure to toxic materials, either human-made or naturally occurring. Some construction processes can pose a risk to worker health through exposure, and during use, materials (Kestner et al, 2010). For instance, materials for stripping paint, sealers, and adhesives can be hazardous to worker health. None or less toxic materials are less dangerous to construction laborers and building inhabitants. Various materials negatively influence on indoor air quality and expose inhabitants to health dangers. Some building materials, for example glues, produce hazardous smokes for just a little time while and after fixing; others can be contributed to air value problems during in the building lifecycle. In addition, even if none-healthy building material does not touch the residents of a building, it will most probable impressive the environment and also labors upstream throughout extraction and construction or downstream throughout destruction and disposal. Architects and

constructors need to be informed about the toxic effects of the products they specify and be aware of less toxic options (Kestner et al, 2010).

2.6.11 Adaptable Material

Adaptable capacity is the skill of a material to answer unknown future needs and changes with minimal effort. Two kinds of adaptability are convertibility and flexibility. Furthermore, convertibility is the capacity to accommodate changes in apply, and also flexibility is the capacity to cause small changes to space use (Moffatt & Russell 2001). Moreover, the benefits of Adaptability contain the next ways (Kestner et al, 2010):

- Answer to any future requirements and also upgrades, replacements and adaptation easier.
- Increases reusable and recycling places by assembly it easier.
- Decreases landfill and waste request by forwarding utilized materials into novel building construction site.
- Growths building life-cycle by helping adaptation, easy maintenance, and improvable durable feature.

2.6.12 Safety

Safety is a main important item to improve quality of human life. Building materials in construction sector should be selected with a reasonable subject of safety to decrease the possibility of any failure. Building structures are expected to be very safe, because of the safety of their inhabitants is of extreme significance (Millais, 2005). To achieve this goal, the chance, or more suitably the possibility, of failure should be considered. This is tried by applying a safe building material to construct structure. Additionally, building engineers and constructors try to avoid use brittle building materials however this is not every time possible (Millais, 2005).

2.7 Measurement of Sustainability

The purpose of this part is to understand what factors best promote or prevent establish the consistency of how sustainability is measured. Measuring what is sustainable in building material and construction can be a complicated task. There are many measurement methods available with new ones being added at a rapid pace and existing ones undergoing frequent changes. It is important to understand that a sustainable choice for one project may not be the best choice for another. How we measure relates to the technical methods behind measurements. Consequently, there is no specific way of how we can measure sustainability. However, there are many different methods are existence to measure sustainability that rating system is one of them (Kestner et al, 2010).

Several developed countries in the world have their own sustainable building rating systems. Since 1990s, there has been extensive development of assessment methods, many of which have subsequently gained considerable success. For example, United States and Canada have Leadership in Energy and Environment Design (LEED), the United Kingdom has Building Research Establishment Environmental Assessment Method (BREEAM) (Alyami & Rezgui, 2012). Therefore, they are all helping the architects and engineers to design and build more sustainable buildings. The Sustainability Construction Task Group (now called the Sustainability Forum) believed that there were too many different measures and that consolidation was required (Pitt Matthew et al, 2009). Table 2 summarizes the number of methods available for measuring sustainable buildings within construction sector;

Table 2. Some of the Famous Methods of Measurement in Building Construction (Pitt Matthew et al, 2009).

Measure	Description
Eco-quantum	Assesses the lifecycle of whole units of construction; for example, glazing systems/structural walls.
Life-cycle Assessment	Evaluates performance of the building through its life. It considers the individual elements, which when used together will affect the overall benefits.
Leadership of Energy and Environmental Design (LEED)	Created by the United States Green Building Council, the Leadership in Energy and Environmental Design (LEED) Rating System was introduced in 1999, and is the most popular green building rating system now in use in the United States. LEED covers the entire construction project process from the design phase to the operation phase. LEED is a point-based rating system. The points are achieved by satisfying credit requirements.
Building Research Establishment Environmental Assessment Method (BREEAM)	Developed for office buildings by the BRE and compares and scores different design strategies for possible pollution and local impact. Some consider the BREEAM assessment techniques to be heavily "feature" orientated – for example providing showers for cyclists although it does some CO2 and energy analysis.
Eco-labels	Used for specific product items, for example light bulbs, paints, etc. and are based on EU standards. These use lifecycle analysis on pre-production, production, distribution, utilization and disposal of the product.
Eco-points	A method of ranking and scoring of different environmental impacts. Different issues are weighted using the points so allowing comparisons to be drawn.
Embodies impact study	A way of measuring the impact of manufacturing construction materials, including quarrying and transport, the construction process, including transport to site and the demotion and disposal of materials at end of life of the building.

As Table 2 shows, there is no a particular method to measure sustainability in building construction area. Also, more methods consider environmental aspect. While sustainability is not just concerning to the environmental issues of materials or buildings, sustainability is connecting to economic and social performances also. For instance, LEED and BREEAM cover economic and social issues poorly in their assessments context. While considerations of economic and social aspects are essential issues in sustainability development (Grace, 2008).

Assessments by a single aspect have received considerably criticism, as a single aspect is normally incapable to measure sustainability complication. In addition, a growing awareness of outward nesses, long-term and risk effects have proposed a greater diffusion for multi-criterion methods. Therefore, this lack avoids the assessment of the economic and social outcomes of sustainable selections and, hence, creates a considerable boundary for sustainability score systems. Researches have displayed that this limit touches any systems, as nearly no system includes economic and social assessments. Therefore, a stability between fullness in coverage and effortlessness of use is hence essential to divide sustainability building rating systems (Berardi, 2012). Because, sustainable development considers attitudes and decision to help cover long-term environmental, social and economic growth in society (Grace, 2008).

Life-Cycle assessment (LCA) is the majority usually used of the above systems (Table 1). LCA is a way used to measure the environmental effects of a product or material at all phases of its life from the Cradle to Grave. This contains the extraction of raw materials, the effects of manufacturing, transport, construction and repairs, through to the end of life disposal of the creation. However, LCA systems measure the environmental model of sustainability without considering social and economic effects. To fit this limit, some researches relate the disaggregation analysis needed for an LCA to an assessment of economic and social consideration. Such a method is interesting for the building sector, such as life cycle cost (LCC) analysis displays a familiar model to construction stakeholders. Life cycle cost (LCC) reflects all the costs over the lifetime of a building such as construction and maintenance. This system is particularly useful when dissimilar alternatives have to be compared.

Consequently, combined LCA–LCC with consideration of society can be useful to sustainability (Berardi, 2012). In other hand, achieving the right balance in any rating systems or methods between sustainability dimensions supports true sustainability (Pitt Matthew et al, 2009).

In conclusion, the best way to measure sustainability is a method that consider whole sustainability aspects. Although a balanced treatment of all three is an ideal goal, however it is not always achievable. In other hand, the most effective method for measurement of sustainability in building construction sector is attention to principles of sustainability accepts.

Chapter 3

EVALOUATION OF SUSTAINABILITY BETWEEN REINFORCED CONCRETE AND STEEL AS STRUCTRAL BUILDING MATERIALS IN NORTHERN CYPRUS

3.1 Northern Cyprus conditions

This part presents the conditions of Northern Cyprus in the context of environmental and socio-economic situations. The reason behind this decision is as mentioned in the past, environment, economic and social aspects are playing significant roles to achieve sustainability in building materials, therefore in this chapter all evaluations are based on these sustainability aspects.

3.1.1 Environmental Conditions

3.1.1.1 Geography

Cyprus is the third biggest Island that positioned is inside the Eastern of Mediterranean Sea. It has a special archaeological sites in adding to many medieval castles. In addition, Cyprus has passed through several periods in its history of civilization. Furthermore, geographical conditions, particularly hot weather, have specific impressed on the architecture of Northern Cyprus equally in urban and rural areas. Likewise, the mines of Cyprus organize a significant part of its natural resources that they contain; clay, marble, plaster-stone, limestone, bentonite, iron oxide and sandstone. Also, they cover in 120 km space beginning east to west (Ozay, 2005). Likewise, Cyprus Island is on the Earthquake district 2, and also problematic soils occur in various areas in the region. Besides, there are wide-ranging research on the characteristics of soil in Northern Cyprus that led by the Civil Engineering

Department, in Eastern Mediterranean University, which exists a prepared investigation laboratory (Celikag & Naimi, 2011).

Figure 7. Map of Cyprus (URL 4)

3.1.1.2 Climate

There is no a specific climatic zone of Northern Cyprus climate condition. However, the climate of Northern Cyprus in context of architectural design considered as Hot-Humid and Composite. Generally, Lefkosa is classified as a region with composite climate with regard to its hot dry summers and rainy winter periods also Grine, Magusa and Guzelyurt are classified as being a Hot-Humid climate (Ozay, 2005). Summers time is hot, and winters are raining and warm that similar to other Mediterranean positions. Throughout the summer period temperatures ranges are between 37 and 40 ° C with 12 hours of sunlight in the whole day. Furthermore, in the winter period, temperature ranges are from 9 to be capable to 12°C. With regard to the data collected in Northern Cyprus, economic, cultural and ecological stability

are nearly relevant to the heritage, climate and location of the Mediterranean state (Isika, 2008).

3.1.2 Economic and Social Conditions

The level of Northern Cyprus economy is small which requires a great proportion of imports for growing stability towards the development of the economy. Furthermore, Northern Cyprus owns great sources such as natural sources, and energy. Hence, energy problems can be a start point for growth of the investment and operating cost. Costs for building construction are also moderately high in Northern Cyprus considering the economic conditions and political sanctions. The key goals of the economic development strategy of Northern Cyprus can be reaching the highest possible rate of development on economic stability, more sensible supply of local income, and also increasing the life standards by making improvements to the social structure and economic issues (Business Policy Group 2, 2004). With regard to the construction sector, companies, which are active in construction, have to be imported many building materials from other places the weaknesses in industry parts of Northern Cyprus. Building construction sector request is also bounded, while the sector request has been rising in the past 10 years, with regard to the growth of investors and migrants in the Northern Cyprus. In addition, political sanction is still a restriction and in many directions has impacts the construction zone. With regard to social aspect, in Northern Cyprus there is a high level of education and people attempt to invest their money in a way to return high profit. Consequently, people tend to regularly invest their money in construction industry or in banks. Additionally, the joblessness is very low, for the reason that the population is low however, it can be affected damagingly (Business Policy Group 1, 2005).

Furthermore, with regard to migration of external sources of investment and migrants, construction sector has earned more and more consideration. This raise in population has transported more progress and opportunities for construction. However, there are some matters which are rather risky for the investors in the Northern Cyprus. For example, the economic crisis, mostly in construction, and striking exchange rate variation puts the investors' motivation down to make a long standing investment. The import of construction building material is another issue that affects the investors' decision.

The building construction sector is playing a significant role in the economic and social progresses of the Northern Cyprus. Furthermore, the building construction sector produces one of the maximum multiplier effects through its wide backward and forward connections with other parts of the economy. Also fortunately, the relative between building construction sector and environment has become a striking part for the current researches in this region (Şafakli, 2011).

3.1.3 Overview of Northern Cyprus Construction Sector

As mentioned in the last part, the building construction sector plays an important role in the economic and social developments in the Northern Cyprus. Therefore, building construction sector should not only be regarded as a means of construction buildings, however should also be regarded for its connections with other parts too. The building construction sector produces one of the maximum multiplier effects through its widespread back and forth connections with other parts (Şafakli, 2011). In general, rural traditional building construction of the Cyprus has been underneath effect of in cooperation agricultural way of life and affordable manufacture although conventional town arrangements of the Cyprus are mostly shaped from the imported

styles and the prevalent cultures. In the old building construction of Cyprus, two different construction methods and materials are used. They are: buildings made of sun-dried clay brick and made of stone materials.

Moreover, in the contemporary construction building sector can be divided into several steps. Throughout the period, 1960–1970, one and two-level buildings were typically built. In addition, the local materials and old-style methods started to lose their popularity for the reason that of the increasing of the use of reinforced concrete in the building structures. But, sensitivity on the design and building elements such as shading devices, orientation, and size of the openings all supported the climatic design (Ozay, 2005).

Figure 8. A form of apartment block (Ozay, 2005)

Next 1970s, the apartment type housing units have been prevalent more. The buildings were built by private people. And also, In 1980s social housing developments were started by the local authorities with the drive of meeting the housing requirements. Furthermore, during the current years next 1990s, the growing population of the cities carried in a deficiency of housing in Northern Cyprus. With the purpose of solve this problem, mass housing construction sector quickly

established. Therefore, these are the standard apartment kind housing units, which are far away from the quality (Ozay, 2005).

Nowadays, inadequate quality control, incorrect isolation of buildings from the external effects, honeycombing caused by improper shaking of concrete, lack of regular maintenance, non-existing professional soil examination that is crucial before building construction and usage of incorrect foundation forms and also are many of the reasons getting problems to reinforced concrete as a structural material. With regard to alternative structure material like steel, there is problem of access to workmanship of these systems for Northern Cyprus. In addition, steel should import from other countries because the lack of any steel production in the Northern Cyprus. Moreover, a high level of salt water underground is a dangerous problem in Northern Cyprus situation especially while the water isolation throughout construction period is not regarded (Celikag & Naimi, 2011).

3.2 Identify of the Building Structural Materials Situations in Northern Cyprus

As the researches show, materials selection for construction building is one of the most important approaches to achieve sustainability. With regard to Northern Cyprus building materials situations, briefly; throughout ancient periods, various building materials were used in the Cyprus Island. In both the Luzinian and Venetian times (1192–1489) stone was the main building structural material, but throughout the Ottoman time (1571–1878) stone was just used for the ground level, as adobe construction was working on the higher levels of buildings. During the British time (1878–1930), stone was used to construct building structure. Also, after 1940, as mentioned in the last part, reinforced concrete was presented to Cyprus. Furthermore,

in the contemporary time, more than 90% of building are constructed by reinforced concrete as structural building material (Isika, 2008).

3.2.1 Observation of Building Beams and Columns Materials in the Famagusta Construction Site

Several construction sites have observed in the Famagusta region. Therefore, when I paid attention to the construction building sites especially building structural material, clearly I understood that, construction companies and buildings owners use same methods and material for all of the construction buildings. With regard to structural materials, I noticed that the reinforced concert is a structural material that using in the all of the building construction sites. According to various type of building materials, the right selection of building materials is important role to achieve sustainability in construction building industry.

Additionally, during the observation various damages on building facades and sites detected that may be caused by using of weakness building materials and the lack of awareness of sensible building materials selection. Furthermore, in the below are photos that show the currently building construction sites and their locations that observed in the in the Famagusta area by author;

Figure 9. The building number 1(Photo taken by author in 27th of December, 2014)

Figure 10. The location of the building number 1 is in Famagusta Salamis Street (Source: taken by Google map in 27th of December, 2014)

Figure 11. The building number 2 (Photo taken by author in 27th of December, 2014)

Figure 12. The location of the building number 2 is in Famagusta Salamis Street (Source: taken by Google map in 27th of December, 2014)

Figure 13. The building number 3 South side (Photo taken by author in 27th of December, 2014)

Figure 14. The building number 3 East side (Photo taken by author in 27th of December, 2014)

Figure 15. The location of the building number 3 is in Famagusta Social Housing area (Source: taken by Google map in 28th of December, 2014)

3.2.2 Official Situation of Northern Cyprus Building Structural Materials

As mentioned (see Part 3.1.2), building construction takes an important place on the economy of the Northern Cyprus and also as population growing continues to rise request for and has strong influence on social life. Therefore, Statistics and Research Department established a typical arrangement in direction to gather private construction and package statistics information which is utilized in this research. These standard arrangements are complete by using their managerial records and promoted to Statistics and Research Department via District Offices of Nicosia, Kyrenia, Famagusta, Iskele and Guzelyurt.

According to Office Building Statistics in Northern Cyprus (TRNC) approximately 99 percent of buildings were constructed by reinforced concrete as building structural material in 2011, and also this situation happened in 2010 as well (Office Building Statistics in TRNC). Consequently, the results came from data collection methods of the research show that reinforced concrete is playing significant role in Northern Cyprus construction sector. In other hand, various kinds of structural materials are used in the world however one of the most typical that using in Northern Cyprus

construction sector is reinforced concrete as buildings beams and columns material. The figure 16 shows that currently reinforced concrete structure constructs the majority of buildings in the Northern Cyprus (see Figure 16).

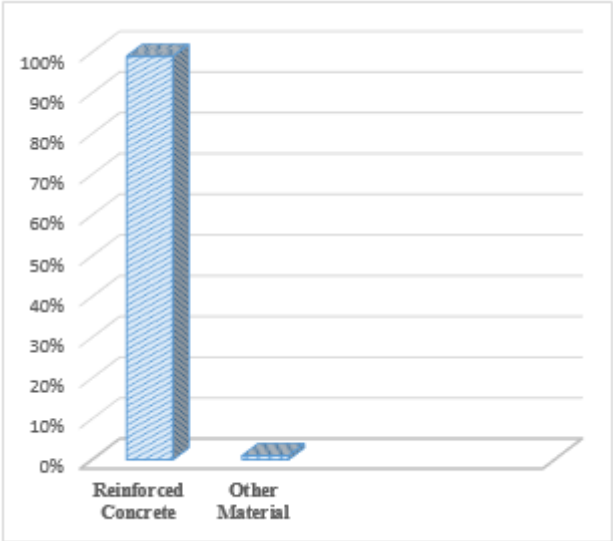


Figure 16. Structural Building Materials Situation in the Northern Cyprus Construction Sector (Office Building Statistics in TRNC, 2011)

3.3 Research Evaluation

Sustainability development balances between environmental, economic and social goals. As mentioned in the last part, in the Northern Cyprus the most common building structural material is reinforced concrete which started to become more popular from mid-1960s (Isika, 2008). With consideration to this study aim, with regard to lack of special sustainability rating system for Northern Cyprus construction sector, it is potential and necessary to applying a based-point rating system. In other words, it is possible to modify a rating system like existing rating system include to sustainability principals with regard to Northern Cyprus conditions.

As aforementioned (see Part 1.4), to clearly achieve understanding about the sustainability of building structural materials, all evaluations of this study are based on comparisons between reinforced concrete and steel as building structural materials in context of most of the important sustainability features. Therefore, with regard to sustainability principal, achieving the right balance in any methods between environmental, economic and social aspects supports true sustainability. According to Pitt Matthew, Mike Riley and Longden (2009); the most effective method for measurement of sustainability in building construction sector is attention to features of sustainability that cover all its aspects. Consequently, the Table 3 shows this study evaluations structure that based on significant features of sustainability in building materials (see Table 3). Furthermore, these features are playing important roles to achieve sustainability (Kim & Rigdon, 1998; Kestner et al, 2010).

As Table 3 shows, the recyclability, embodied energy reduction, reusability, waste reduction measures**,** local materials, durability and pollution prevention measures in construction features have phenomenal positive impacts on environmental aspect of sustainability. Additionally, recyclability, reusability, low life-cycle construction cost, durability and adaptability features have impressive positive influences on economic aspect of sustainability.

Finally, waste reduction measures, pollution prevention measures in construction, healthy material, adaptability and safety features have significant positive effects on social aspect of sustainability. Therefore, to achieve true comparison between reinforced concrete and steel as structural building materials in Norther Cyprus construction sector, in this study evaluations based on these significant features that they cover all sustainability aspects such as environment, economy and society.

Table 3. The features of sustainable building materials (Kim & Rigdon, 1998; Kestner et al, 2010)

Features of Sustainability	Environmental Aspect	Economic Aspect	Social Aspect
Recyclability	•	•	
Embodied Energy Reduction	•		
Reusability	•	•	
Waste Reduction Measures	•		•
Use of Local Materials	•	•	
Low Life-Cycle Construction Cost		•	
Durability	•	•	
Pollution Prevention Measures in Construction	•		•
Healthy Materials			•
Adaptability		•	•
Safety			•

- *Phenomenal Positive Impact*

3.3.1 Evaluation of Recyclability Between Reinforced Concrete and Steel

Raw materials extractions impact on the environment by their refinement processes and transport until they come to be building parts. Therefore, there are limits to intact natural resources and recycling decision is probably one of the best remedies to improve environmental performance in several cases. In fact, recycling offers the opportunity to decrease the using of raw material through using recycled building materials. With regard to construction field, the highly recyclable material should have straight impacts reducing CO2 emissions, use of raw material and natural resources and finally, energy consumption. By using of recycled building materials, the supposition is that the environmental effect is lowered. Also, recycled building materials can come from both post-consumer and pre-consumer sources (Berge, 2009).

The recycling of building materials cannot consider for all materials that finish their lifecycle and bring back to the industrial phase with regard to the massive quantity of raw materials that are required to elaborate some kinds of materials, for instance, reinforced concrete and other materials that decline their acts in their recycled positions (Maccarini V & Avellaneda, 2013). With regard to Northern Cyprus conditions the reinforced concrete is used for majority of the building structure however, reinforced concrete is a low recyclable material and required significant energy to recycle (Berge, 2009).

In contrast, the content of the steel can be recycled therefore, steel is simply recyclable material (Burgan & Sansom, 2006). Therefore, the recyclability potential of steel is in highest level. The considrable fact here is that steel is nearly fully recyclable by almost over 90%. Hence, this means that steel material can be recycled

multiple times while keeping its quality. By this means this quality is unique for a building structural material. Thus as a result, steel recovery establishes positive influence on the environment. Furthermore, utilizing steel to construct building structure can make it easily to apply changes to structural plan or repair the injured components (Berge, 2009). The some of the main advantages of recycling steel are that (Burgan & Sansom, 2006):

• Use of natural resources is reduced,

• Energy use is reduced with regard to decrease extraction activities of raw materials,

• There is a decrease in waste generation of building material,

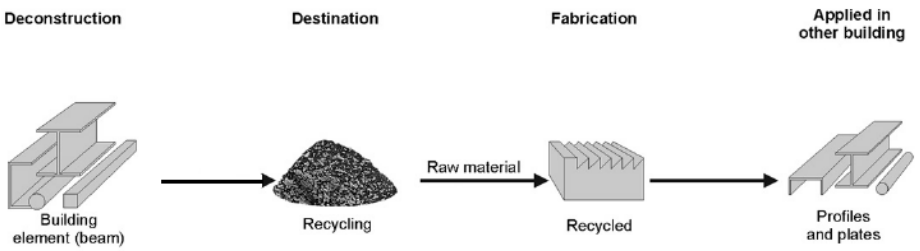


Figure 17. Possible destinations for steel at the end of building life cycle (Maccarini V & Avellaneda, 2013)

The general trend in the world is to use more recyclable building materials like steel in the construction sector. With regard to Northern Cyprus conditions, the environmental impacts of using reinforced concrete in building sector can be reduced by replacing it with steel. Because, as mentioned before, the high recyclable materials like steel directly affects the decrease of CO2 emissions, waste generation and also use of raw material. In this study, steel is considered in the high level of recyclability feature while reinforced concrete with regard to its properties that mentioned in this part, is considered in the low level of this feature.

Table 4. The evaluation's result of recyclability between reinforced concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Recyclability	1	3

Note: Low: 1, Medium: 2, High: 3

3.3.2 Evaluation of Embodied Energy Reduction Between Reinforced Concrete and Steel

The one of the key way of decrease greenhouse gases emission is attention to embodied energy in building material sector. It is the energy consumed through all of the procedures related with the construction of a building, from the extraction of natural materials to manufacture, transportation and product delivery. Selecting materials with low embodied energy influences at this phase hence has potential to considerably decrease a buildings lifecycle impacts. Usually, embodied energy relates to materials constructing, transportation to the building construction site, and construction actions (Guggemos et al, 2005).

Several researchers identify the reinforced concrete as the key structural material, which has a relatively Low embodied energy in its construction phases. The table blow shows that embodied energy of usual construction building materials. As the Table 5 shows, the embodied energy amount of concrete is 1.3 MJ/kg that takes place nearly in the low stage of embodied energy level. Therefore, with regard to this data the low amount of concrete is a positive point of consideration sustainability.

Table 5. Embodied energy for usual building materials (Kibert, 2012)

Material	PER embodied energy (MJ/kg)
Stone (local)	0.79
Concrete	1.3
Concrete precast	2.0
Clay-bricks	2.5
Gypsum plaster	2.9
Gypsum board	4.4
Cement	5.6
Recycled Aluminum	8.1
Recycled Steel	8.9
Plywood	10.4
Glass	12.7
Fiberglass insulation	30.30
Steel	32
PVC	70.0
Polystyrene insulation	117.0
Aluminum	227.0

However, steel as a structural building material has been categorized as having high embodied energy with regard to its process of production. Moreover, the cause of this fact is fabrication process of steel. Generally, production of more embodied energy typically has higher environmental impact with regard to the greenhouse gas related and emissions with the energy consumption. Embodied energy includes whole energy consumed in extraction processes of raw materials, manufacturing, transportation and also installation activities in construction sites (Kibert, 2012). Consequently, concrete is in the high level of embodied energy reduction (see Table 5) while, with regard to Northern Cyprus conditions by lack of any steel production, steel required to be imported from other countries therefore this issue can reduces the embodied energy production in manufacturing proses of steel. Therefore, in this

research steel is classified as a material with medium level of energy embodied production (see Table 6).

Table 6. The evaluation's result of Embodied Energy Reduction between reinforced concrete and steel (proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Embodied Energy Reduction	3	2

Note: Low: 1, Medium: 2, High: 3

3.3.3 Evaluation of Reusability Between Reinforced Concrete and Steel

Reusability is exactly the using again of a building or building element. In addition, the second life of a reused element can be the same as the unique use or quite different. Majority of sustainable construction guidelines encourage the usage of reusable building materials in new construction, and for worthy reason. Utilizing reusable building materials diverts possible waste from landfill, decreases the consumption of new materials, and often donates to the aesthetics of the new building construction (Kestner et al, 2010).

With regard to this study subject, reinforced concrete, especially its cast-in-place construction style is a difficult material to divert for reuse and adaptability. Therefore, the reasons for the difficulty of adapting and deconstructing cast-in-place reinforced concrete contain the following ways (Kestner et al, 2010):

• Removal of separate columns or beams becomes complicated and the outcome is not a clean cut components for reuse. Because of the construction style of reinforced concrete.

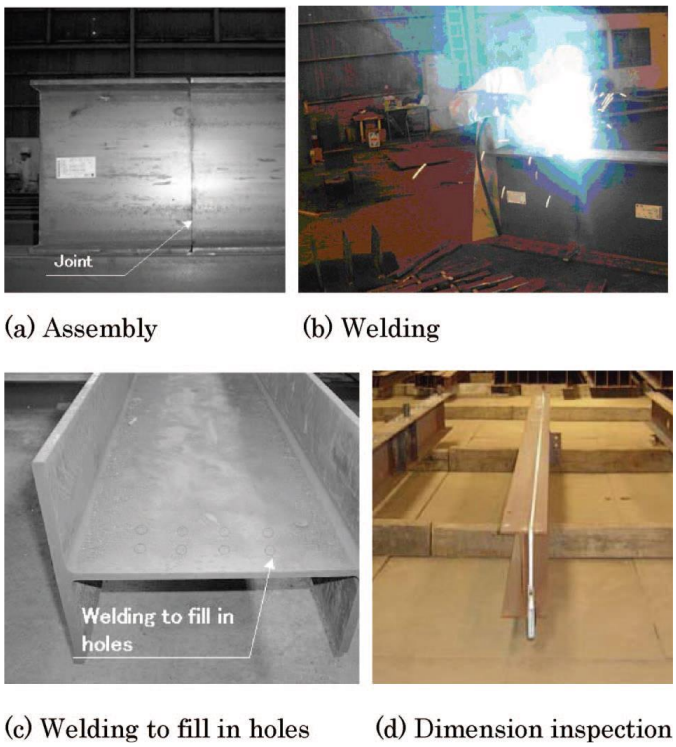
• Members are heavy-weight and difficult to transfer.

• According to reinforced concrete shape, workers cannot check reinforcing bars from the facade, so without as-constructed or unique structural details it becomes problematic to assess a given helping of the structure for future reuse elsewhere.

• The lack of tried-and-true fastening approaches makes elements hard to reuse.

In contrast, Steel by its nature, is the only kind of structural component that can be reused. Even without particular linkages that help destruction work, steel elements can be reused after negligible reprocessing processes such as cutting, welding and drilling. Steel experiences no major changes owing to aged, except for corrosion and

plasticization caused by extensive earthquakes. The satisfaction of steel is high for reuse with regard to its useful properties. Corrosion problems can be fixed by painting and also plasticization caused through earthquakes can be controlled by assuming damage control strategy utilizing a seismic design method in which structural components are preserved within an elastic area by identifying seismic energy-absorbing components (Fujita & Iwata, 2008). Destruction of steel structure components are easier than reinforced concrete. Where these structural components are reused, a rolled H-section of joining performance necessities can be met by just altering the connection components and steel bars. For instance, Figure 19 shows fabrication processes specific to reusable components include welding to joint structural members, welding to fill in holes in addition to reinforcement of openings (Fujita & Iwata, 2008).



(a) Assembly (b) Welding

(c) Welding to fill in holes (d) Dimension inspection

Figure 18. Fabrication procedures for reusable components (Fujita & Iwata, 2008)

To conclude, steel has a considerable potential to reuse after destruction building structure in new construction proses. This advantage has strongly impact on environmental and economic aspects, and also it brings social benefits, such as improve adaptability of building structure to any changes in future. Therefore, with regard to existing knowledge that mentioned in this part, steel is a high reusable structural building material. In contrast, it is more difficult to reuse reinforced concrete components in the other construction project, because reinforced concrete components construct widely by cast-in-place style in Northern Cyprus building construction sector. Therefore, reinforced concrete is considered in the low level of reusability feature (see Table 7).

Table 7. The evaluation's result of reusability between reinforced concrete and steel (proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Reusability	1	3

Note: Low: 1, Medium: 2, High: 3

3.3.4 Evaluation of Waste Reduction Measures Between Reinforced Concrete and Steel

Decreasing waste in the construction procedure growths the source efficiency of building materials. Additionally, minimum construction waste throughout fixing decreases the necessity for landfill space and likewise delivers economic benefits (Kim & Rigdon, 1998). The considerable use of materials results in growing totals of solid wastes, which are cast-off or burned. This results not simply in a loss of valuable materials, however also in harmful environmental and health impressions.

Furthermore, waste is becoming a large problematic issue in contemporary construction sector, as we are finishing of land for landfilling, and also end-of-life waste action has strongly negative environmental and health influences (Worrell & Reuter, 2014). In addition, waste is just waste if it cannot be utilized again or if it's economic worth, counting dumping costs, is not satisfactory to make its utilization economically possible. Recyclability and reusability enables waste to become a source; though unfortunately several aspects hinder it becoming completely recyclable and reusable. Recycling and reusing are the reprocessing of retrieved building materials at the end of production life, bringing back them into the supply chain (Worrell & Reuter, 2014). Therefore, recyclability and reusability are playing significant role to decrease waste in building construction sector. Consequently, the recyclability and reusability result in less waste. Nevertheless, even if materials are completely recycled or reusable after or during the construction procedure, gathering and handling fees, with regard to transportation, detectable amounts of money should be spent to recycle or reuse materials. However, the using of steel, which may be

reused several more times and also can be recycled easily than reinforced concrete, decreasing total construction waste (Kestner et al, 2010).

With regard to Northern Cyprus condition, there is minimum skill available to recycle materials and also typically reusing approaches for on-site construction. Hence, the most effective resort to enhance the current condition of waste organization in construction sector of Northern Cyprus, is to minimalize the produced waste, or to attempt to apply materials which can be reused on building construction site.

Generally, it seems more reasonable to minimalize waste in the first place so it is not required for effort to recycle or reuse. However, with regard to this study, as mentioned in the last part (see Part 3.3.3), heavy steel elements, such as beams and columns can be reused in construction building and also they have high potential of recyclability, therefore these are the significant reasons that steel is classified in the high level of waste reduction measures. In contrast, with regard to lack of any potential to reuse reinforced concrete components such as columns and beams, also low level of its recyclable capability, in this study reinforced concrete is considered in low level of waste reduction measures feature (see Table 8).

Table 8. The evaluation's result of waste reduction measures between reinforced concrete and steel (proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Waste Reduction Measures	1	3

Note: Low: 1, Medium: 2, High: 3

3.3.5 Evaluation of Local Materials Between Reinforced Concrete and Steel

Local sourcing of building materials are regularly part of the conversation in sustainable building design. Local sourcing means that natural resources are extracted or harvested in the region near the project site. There are some convincing reasons why sustainable construction would favor using materials and systems that originate from local sources. This approach reduces transportation energy, carbon emissions, and air quality influences due to the transport of materials. For the reason that, transportation energy accounts for about 20 to 25 percent of total construction energy, which translates to 20 to 25 percent of carbon dioxide greenhouse gas emissions (Kestner et al, 2010).

There are additional benefits for instance, using local materials sometimes encourages vernacular building styles, which may be appropriate choices for the given climate or for historical or cultural reasons. Local sourcing also more directly connects users with the impacts of their choices, although it cannot by itself produce sustainable thinking about resource use. And also, transferring coarse aggregate materials for great distances are typically damageable. Therefore, there is this a considerable advantage in utilizing local materials (Ambrose & Tripeny, 2011).

There are multiple meanings of how far away can be considered as local to a given project site. For small-scale construction, particularly in a rural or residential context. However, community members' definition of local might be limited to whether things can reasonably be brought to site by car or even by foot (Kestner et al, 2010). Therefore, in this thesis, the material that existing in the Northern Cyprus area are considered as local materials by author.

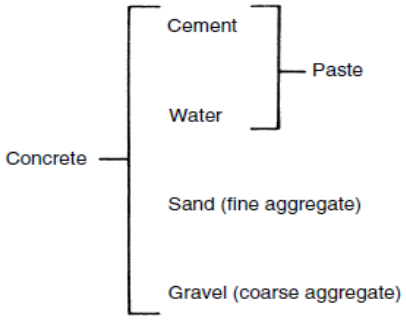


Figure 20. Composition of the concrete material (Ambrose & Tripeny, 2011)

The most frequently used mix is one of normal Portland cement, clean water, average-to-coarse sand, and a significant volume of properly large granules of rock. Figure 18 shows the mixture of normal structural concrete. The binder contains cement and water, chemical response results in the hardening of the physique. Also, to construct reinforced concrete structural beams and columns steel reinforcement was used, that the essential purpose of steel reinforcement is to reduce cracking of the concrete due to tension stress (Ambrose & Tripeny, 2011). As mentioned in the past (see Part 3.1.3), steel should be imported from other country. Therefore, for this situation, the building materials that should be imported of other country to Northern Cyprus are considered as non-local building materials. Consequently, steel is not local material to construct structural beams and columns in the Northern Cyprus construction sector.

Finally, local materials have environmental benefits which should be weighed, along with many other factors while selecting materials. The use of local materials reduces the expenses for shipping heavy building materials and the associated energy and emissions. These are good reasons for encouraging the use of existing local materials. With regard to this evaluation, steel is considered as a non-local material because of the lack of any steel production in Northern Cyprus. In contrast, there are

many sources of sand and gravel to make concrete. However, cement as a main important concrete material should be imported from other countries, and also to make reinforce concrete constructors need to import steel reinforcement from other countries. Therefore, reinforced concrete is considered in the medium level of local materials feature (see Table 9).

Table 9. The evaluation's result of local material between reinforced concrete and steel (proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Local Material	2	1

Note: Low: 1, Medium: 2, High: 3

3.3.6 Evaluation of Low Life-Cycle Construction Cost Between Reinforced Concrete and Steel

The life-cycle construction cost is the cost to construct building from the start of the process of construction until the stage that building is finished. From an economic point of view the ideal goal of cost optimization of building material should be minimizing the total building life-cycle cost that includes construction and maintenance costs. As we know, reinforced concrete is a widely used construction material in Northern Cyprus construction sector to construct structure beams and columns. The main reason to use reinforced concrete as a structural material in Northern Cyprus is the lack of other material production like steel. Furthermore, by the reason the lack of steel production in Northern Cyprus, consequently steel has to be imported from other region (Celikag & Naimi, 2011). Therefore, at the first view, it seems that the construction cost of steel is higher than reinforced concrete with regard to lack of any exciting productions.

However, some researches showed that the life-cycle construction cost of reinforced concrete is more than steel. For instance, the results gained from inquiries on the economic aids of utilizing steel structure building instead of the reinforced concrete structure proved the economical side of steel structure due to the contributed advantages of speed of construction, lighter weight, and more flexibility, etc (Celikag & Naimi, 2011).

Furthermore, extra weight in building materials will increase the life-cycle construction cost. For the reason that, when weight of part of building is high construction processes need more materials and methods to construct, hence the cost of construction gets rapidly growing. In general, steel structural material with speed

of construction and a lighter material than reinforced concrete, has higher efficiency linking to the life-cycle construction cost then concrete (Celikag & Naimi, 2011). For instance, one research noted the life-cycle construction cost of reinforced concrete structure for a residential building in Famagusta is nearly 26 percent upper than the life-cycle cost of the steel structure in the same building. Consequently, the construction of steel material that using to construct beams and columns is reasonable for the economic aspect more than the reinforced concrete (Afshar, 2009). Generally, reinforced concrete production is more time consuming and needs intensive work. Therefore, these factors increase the life-cycle construction cost in during the building construction because of reinforced concrete needs more time to ready and labors to protect. In other hand, the use of steel construction material may accelerate the construction process of structures which leads to preserving in the life-cycle cost of the project and therefore positively leads to the region economy.

With regard to maintenance cost, it depends on the type of building material used in the construction. The maintenance cost includes check, repair, and replacement costs. Therefore, properties of building materials are playing significant role to reduce the maintenance cost of building. Reinforced concrete is a unique complex building material that is porous and extremely heterogeneous (Berge, 2009). In this kind of material even if repair is done, the primary strength many not be achieved because of heterogeneous property of material context. Therefore, during maintenance period often reinforced concrete had to be fully destructive which makes more time taking and as a result that make it more expensive (Sarma & Adeli. 2002). Therefore, it means that reinforced concrete can increase the maintenance costs.

In contrast, with regard to important of flexibility in maintenance cost stage, Steel is to be able to make easily any changes therefore, it can be decreased the cost of maintenance. What is more, keeping steel isolated from the outside impressions and its protection against corrosion is easier than the separation of reinforced concrete. In addition, when structural components are injured that it needs substitute then it is easier on the pocket to repair steel than reinforced concrete structure (Celikag & Naimi, 2011). Consequently, maintenance with minimum loss of occupancy, cost and time is one of the significant positive fact by using steel as structural building material (Sarma & Adeli. 2002). However, the lack of enough experience of steel properties and skilled labors to repair steel structures is another problem with regard to region conditions. But, the flexibility of steel is a considerable character that has significant impact on reduction of maintenance cost.

Finally, with regard to the Northern Cyprus conditions at the firs view it seems that the construction cost of steel is higher than reinforced concrete. However, with regard to steel properties that mentioned in this part such as, reduction working time, less total weight and more flexible than reinforced concrete, life-cycle construction cost of steel is lower than reinforced concrete. Therefore, steel can be considered in medium level of low life-cycle construction cost feature by consideration to compare with reinforced concrete. In general, life-cycle construction cost of reinforced concrete is higher because of it needs more time and work, it has higher weight than steel in the same situation, and also it needs some materials to be imported like cement and reinforcing bars to construction building structure. Therefore, in this study reinforced concrete is considered in the low level of this feature (see Table 10).

Table 10. The evaluation's result of low life-cycle construction cost between reinforced Concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Low Life-cycle Construction Cost	1	2

Note: Low: 1, Medium: 2, High: 3

3.3.7 Evaluation of Durability Between Reinforce Concrete and Steel

Durability is determined as "the ability of a building or any of its components to perform its required functions in its service environment over a period of time without unforeseen cost for maintenance or repair" (Canadian Standards Association, 2007). Therefore, durability of building material is playing important role to decrease the maintenance cost, also it can be reduced total life-cycle building cost. Consequently, the high durability of structural building material has a positive effect of economic aspect. Therefore, achieving durability is a fundamental principle of sustainable design (Kestner et al, 2010). Therefore, good durability should be a goal for every building construction project. In general, the durability issue should always be an integral part of the structural design for the given structure.

Reinforced concrete is known as a high durable structural material. Reinforced concrete structures can be designed to stand a useful life up to 100 years and the material itself can remain sound after hundreds of years' exposure. However, it can also fail dramatically after only a few years. Frequent changes in weather, cracks, shrinkage, and corrosion of reinforcements may reduce the life of a reinforced concrete structure. But, well-designed, compressed and cured reinforced concrete can indeed be very durable (Mays, 2002). Considering high level of salty ground water in Northern Cyprus, the corrosion on steel reinforcement is a big problem if the water isolation is not adequately applied and taken seriously during the construction. This may cause corrosion of reinforcing bars inside the lower parts of the column leading to cracks on the lower parts of the concrete column (Celikag & Naimi, 2011). In addition, problems with the durability of many reinforced concrete structures arise due to insufficient knowledge of the life of building materials and the effectiveness

of good detailing on the engineers' side, as well as how the quality of workmanship on site the can influence on construction (Mays, 2002). Additionally, broad experience shows that durability of reinforced concrete component is related not just to material and design also, to how reinforced concrete production work is carried out and the quality of construction also.

Steel materials in aggressive environments, in presence of water and oxygen, have a tendency to develop processes of corrosion that can be very damaging for the durability of the structure. In order to prevent these phenomena, it is essential to ensure that the surface of steel elements exhibits sufficient corrosion resistance (Simões da Silva et al, 2012). The durability of a steel structure depends essentially on its protection against corrosion. Corrosion is a chemical process of degradation of the steel, which grows in the presence of humidity, oxygen and existing pollutant particles in the environment. Therefore, by consideration to Northern Cyprus conditions the durability of steel building structural beams and columns material is lower than reinforced concrete, for the reason that corrosion on steel is significant problem for building structure because corrosion can still occur over time. However, this problem can be solved by preventive actions such as the use of anti-rust paint to prevent corrosion of steel (Simões da Silva et al, 2012).

In conclusion, all constructors should be aware of durability of building materials because high durability can be reduced the maintenance and repair cost of building, therefore, high durability can be classified as a significant economic benefit in the construction sector. The durability of reinforced concrete is a very positive characteristic in the Northern Cyprus conditions. Concrete is a material that can last a very long time, however steel reinforcements in reinforced concrete are very weak

against salt water corrosion and wet weather. In contrast steel is a very weak building material against corrosion, this problem can still occur over time. Finally, with regard to Norther Cyprus environmental conditions such as geographical and weather the durability of reinforced concrete is higher than steel, which is why it has received high level of this feature (see Table 11).

Table 11. The evaluation's result of durability between reinforced concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Durability	3	1

Note: Low: 1, Medium: 2, High: 3

3.3.8 Evaluation of Pollution Prevention Measures in Construction Between Reinforced Concrete and Steel

The pollution of construction building can be effects on the resident population in terms of local transportation problems, noise, dust, disturbance or nuisance mostly. Generally , we have to be aware of the impacts from pollution that extraction, transport and construction of materials will have on the natural habitat, pollution of air, ground and surface water, local residents, and any specific social features of note (Halliday, 2008).

Accordingly, reinforced concrete is generally used as a structural building material in the Northern Cyprus construction sector, therefore according to many researches one of the main disadvantage of using reinforced concrete with regard to pollution reduction in construction site is production large amounts of dust during its construction period. In contrast, steel produces less dust in its construction period than concrete, because of the steel construction is classified as a dry construction method. However, steel production can be increased the noise pollution during its construction building (Celikag & Naimi, 2011). As mentioned in the last part, the style of steel construction is a dry method. Therefore, this makes for direct use, and there is no wait for the structure to settle or dry. Also, when steel is carried on construction site, there is no necessity to cut it or sand it down; it is normally carried ready to install. Consequently, this is an important advantage because it reduces the production of dust and to avoid chemical interactions. This reduces the dust that construction labors may breathe in with other building materials that necessity cutting and sanding, which avoids damaging health impacts to the lungs (Simões da Silva et al, 2012).

To conclusion, fabricated construction style is a significant advantage of steel to construct structure beams and columns. The significant benefits of using steel can be classified in these ways; reducing dust pollution, and reduction in health hazards and less wastage (Simões da Silva et al, 2012). With regard to these issues, steel can be classified in the high level of pollution prevention measures in construction feature. In contrast, reinforced concrete can be considered in the low level of pollution prevention measures in construction feature with regard to its construction style (see Table 12).

Table 12. The evaluation's result of pollution prevention measures in construction between reinforced concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Pollution Prevention Measures in Construction	1	3

Note: Low: 1, Medium: 2, High: 3

3.3.9 Evaluation of Healthy Material Between Reinforced Concrete and Steel

All architectures and constructors have to be aware of what effects building materials may have on the health of workers on construction site. Several of the products we determine cover or could release toxic materials that can touch human health. Therefore, by decreasing the use of materials covering such toxins (or which produce poisons in intermediate phases of manufacturing and construction that may not take place in the completed product), we decrease the risk of contact to together the environment and social beings. For that reason, structural engineer's necessity to be knowledgeable about the toxic impressions of the materials they require and be aware of less toxic possibilities (Kestner et al, 2010).

The below there are listed some important with possible toxicity effects of structural materials (Kestner et al, 2010);

Steel: galvanizing, paint, transport and emissions during construction.

Reinforced Concrete: admixtures, curing compounds, form-release agents, sealants, joint materials, water stops, and emissions during manufacturing and transport (such as cement kilns);

Structural engineers can contribute in many ways to efforts to mitigate the adverse effects of toxic chemicals with investigate structural materials for toxicity impacts, and Avoid the use of materials that contain or release substances known to be highly toxic to human health.

Construction workers are at risk for several health hazards. For instance, with regard to reinforced construction styles, when exposed to Portland cement, the greatest

common ingredient in concrete. Dangerous materials in wet concrete and mortar contain calcium oxide which corrodes human tissue, crystalline silica which abrades the skin and can injury lungs, and chromium that can reason allergic reactions (Sahai, 2012).

In addition, skin contact can reason some major skin irritation. The dangers of wet cement are due to its drying, caustic, and abrasive properties. If skin comes in contact by wet cement for a little period of time, the irritation is negligible. Likewise, allergic reactions may also grow from working by cement for a long time. In other hand, dust in the air can irritate the eyes, make happen chemical burns, redness or in the worst events, blindness. Inhaling deeply dust caused through grinding, sanding, or cutting concrete can leading to an often fatal lung illness called silicosis. Many studies have linked crystalline silica exposure and lung cancer. Therefore, reinforced concrete is a material that poses several risks for those that install it on the construction site (Berge, 2009). As a result, with regard to concrete hazards for workmanships in the construction site, reinforced concrete can be classified as a construction material in the low medium level of health for construction workers (Table 13).

In contrast, with regard to steel situation, the smoke from welding and cutting is the extreme health dangers for workers and engineers if the steel is covered with lead-based paint. In addition, according to Infrastructure Health and Safety Association (IHSA), “lead poisoning can occur when you inhale or ingest lead dust and fumes during burning or welding of steel structures coated with lead-containing paints”. Signs of lead poisoning vary from vomiting and nausea to paroxysms or seizures in the more dangerous cases. In general, the smokes from welding, cutting and eyes irritation make happen by welding steel are the extreme health dangers of using steel

as structural materials for workers in the building construction site (Berge, 2009). When taking steel construction style into consideration, which is classified as a dry construction method, steel has less dangerous impacts on the construction workers and engineers, in the construction site, than reinforced concrete. However, by consideration to steel construction hazards, which are mentioned in this section, steel is considered in the medium level of healthy material feature (see Table 13).

Table 13. The evaluation's result of healthy material between reinforced concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Healthy Material	1	2

Note: Low: 1, Medium: 2, High: 3

3.3.10 Evaluation of Adaptability Between Reinforced Concrete and Steel

Adaptability is not a new method however, it has become more popular by the growth of sustainable design. That is since buildings stay the unchanged while user necessities and technologies can normally change over their life. A building requirements to be constructed in a method that provides to answer any new user necessities. Having a plan for future reprocess of materials connected in buildings creates it easier for the next group of builders to reprocess materials from nowadays buildings once they are no longer required.

Besides, adaptability will make it more probable that the building will be long-lasting thus growing social benefit. Structural materials normally description for the majority of the materials in construction. That is why construction engineers play the leading role in defining which structural materials and elements are utilized and how they are linked together, causing them a key player in applying adaptability approaches (Kestner et al, 2010). Therefore, structural engineers should be selected the materials that make buildings easier to adapt.

With regard to this study subject, reinforce concrete particularly cast-in-place (the method that use in Northern Cyprus construction sector), is a challenging structural material to consider for adaptability. Furthermore, the reasons for the difficulty of adaptability are as follows (Kestner et al, 2010):

- Reinforce concrete structures are always whole with few, if any, connections between its components. Removal of individual components (beams or columns) is inevitable and the outcome is not a clean cut component.
- Its components are heavy and difficult to move.

- Its components are normally custom-designed for specific applications, causing them unlikely to conform to the necessities of other projects.
- Reinforcing bars cannot be seen from the exterior, making it difficult to evaluate a given helping of the structure for future needs without as-built or original structural details.
- The lack of tried-and-true fastening approaches makes components hard to adapt.

In contrast, steel clearly is a very logical candidate for any adoption, as steel is not monolithically cast into the structure somewhat, it is brought to construction site in prefabricated gatherings that are installed in piecemeal form. Therefore, with regard to adaptability, the without intrusive the field work, the more reasonable the use of domesticated components in the future. For example, by making use of bolted field connections rather than welded ones, the act of separating the materials is much simpler; the demolition contractor needs only to remove the bolts, rather than going through the work of gouging out welds (Pulaski et al, 2004).

The advantages of steel structures with regard to adaptability are (Simões da Silva et al, 2012):

- Steel structures are easy to dismantle, letting the removal and collection of parts of the steel components.
- Steel components are high reusable and are easily moved from one place to another.

Architectures and constructors should keep their attention for on the future as designing elements, and also for probable extending and any changing in the future. Materials selection should be carefully based on any future possibility requirements. Steel components are good choices for adaptability projects, since the components may readily be designed for disassembly. Consequently, as mentioned in this part adaptability of reinforced concrete is low, while steel is called as a high adaptable building structural material (see Table 14).

Table 14. The evaluation's result of adaptability between reinforced concrete and steel (Proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Adaptability	1	3

Note: Low: 1, Medium: 2, High: 3

3.3.11 Evaluation of Safety Between Reinforced Concrete and Steel

Any continuous action to decrease dangers, risks and unsafe developments should be applied in human spaces occupied, particularly in buildings. Therefore, structural building materials must be selected with a satisfactory issue of safety to decrease the possibility of failure. Steel lower weight in this structural kind with compare to reinforced concrete in the same conditions is another significant feature that should be careful with regard to the short soil bearing capability in Northern Cyprus. On the other hand, Cyprus Island is in the Earthquake zone 2 hence, constructors every time try to keep the weight of the structure at a lowest potential level for improved the behavior of building structure (Celikag & Naimi, 2011). This can be achieved by using lighter construction materials, such as steel structural material. In addition, other problem of reinforced concrete is the high potential of human mistakes in construction process with concrete.

Reinforced concrete is a useful structure system for fire resistance. It is a benefit of using reinforced concrete as structural material by consideration safety feature. In contrast, steel is very weak in the face of fire. In addition, it finally becomes very weak and fails (Jacobs, 2007). Furthermore, the up stage of underground salt water is a dangerous problem in Northern Cyprus situation especially when the water isolation throughout the construction period is not considered. Therefore, this situation can be a dangerous problem of specially reinforced concrete. For the reason that corrosion on steel reinforcement inside the foundations and then lower parts of the column in concrete structure (Celikag & Naimi, 2011).

In general, many researches show that there are many problems to construct a safe building in Northern Cyprus such as skilled workers, incorrect detailing, lack of

quality checking which contributes to problems throughout construction actions, lack of water isolation, and lack of soil analysis and also high level of salty groundwater (Celikag & Naimi, 2011). Consequently, with regard to Northern Cyprus conditions, there are serious problems for both of reinforced concrete and steel in context of safety feature. For example, by considering to low soil bearing capacity in Northern Cyprus it can be dangerous factor for reinforced concrete structure, because of the weight of reinforced concrete is high than other structural materials like steel. And also possible corrosion on steel in Northern Cyprus environmental condition is another considerable problem for constructors and structural engineers. Therefore, in this study steel and reinforced concrete are considered in the same level of safety feature because both of them have some disadvantages with regard to Northern Cyprus' conditions (see Table 15).

Table 15. The evaluation's result of safety between reinforced concrete and steel (proposed by author)

Feature of Sustainability	Reinforced concrete	Steel
Safety	2	2

Note: Low: 1, Medium: 2, High: 3

3.3.12 Result of Evaluations

In this thesis, reinforced concrete as a commonly used structural beams and columns material in the Northern Cyprus construction sector and steel, as an alternatively used structural material, are evaluated in regard to some important features of sustainability that cover whole aspects of sustainability. Therefore, reinforced concrete and steel were compared by these features. The Table 16 shows the results of evaluations between reinforced concrete and steel in Northern Cyprus construction sector in context of some of the main sustainability features.

Recyclability and reusability were playing significant role in environmental and economic aspects of sustainability in this research. For the reason that recyclability and reusability, have important effect on sustainability principals like reduction of use of raw materials and decrease waste generation. As the Table 16 shows, the capability of recyclability and reusability of steel is in satisfactory level. However, reinforced concrete is a structural building material with low recyclable and reusable possibilities.

In addition, by consideration to the use of local material feature, as we know, this feature has environmental benefits and should be considered. The use of local materials can be decreased the transportation impacts, the related energy and also emissions. The evaluation of local material feature showed (see Table 16) that in Northern Cyprus there are some concrete ingredients, such as sand and gravel, therefore it is a positive point of using concrete but cement and steel reinforcement, as the main concrete materials, should be imported. In contrast, to construct steel building structure whole steel elements should be imported from other countries, because there is not any steel production in the Northern Cyprus. Hence, steel can

classify in the low level of local material feature with regard to compare with reinforced concrete. In addition, the benefits of using steel is more than reinforced concrete by consideration to pollution reduction feature. The cause for this issue is that steel products lees dust in the air during construction period and has a fabricated construction method therefore it can be reduced pollution (see Table 16).

Whit regard to the economic aspect of sustainability, the main purpose is reduction of the life-cycle cost of building that, it includes, total construction and maintenance costs of building. Therefore, by consideration to this aim construction cost, maintenance cost and durability of building materials are significant issues. Hence, the results show (see Table 16) that the use of steel has more economical benefits than reinforced concrete with regard to reduce life-cycle construction cost. In other hand, the life-cycle construction cost of steel are less than reinforced concrete.

At first glance, it seems that the price of steel used for construction in Northern Cyprus is more than reinforced concrete because the lack of steel production. However, as some researches showed (Part 3.3.6) the life-cycle construction cost of steel structure is less than reinforced concrete in the residential buildings, with completely the same conditions in Northern Cyprus. In addition, as mentioned in the part 3.3.7 the durability of building material is playing an important role to decrease the maintenance cost, and also it can reduce the use of raw materials. In this study the rate of durability feature of steel is low because it is very weak against corrosion in context of Northern Cyprus conditions such as weather situation. In contrast, concrete is a durable building material under the Cyprus Island environmental conditions (see Table 16).

Moreover, adaptability, healthy material and safety features are playing significant roles of social sustainability in the building construction sector. Adaptability feature is very useful to achieve sustainability in the construction sector because buildings need to be designed and constructed in a way that enables to answer to any human future needs. Therefore, as you can see in the part 3.3.10, steel is a high adaptable structural building material (see Table 16), while the adaptability of reinforced concrete as a structural building material is low. In addition, With regard to healthcare issue in the construction sector, by consideration to reinforced concrete, steel properties and their construction methods, both of them have some hazards on human health. However steel construction hazards are less than reinforced concrete, because of the less potential toxicity impacts of steel and steel structure construction is classified in the dry construction method (part 3.3.9).

In this study, steel and reinforced concrete are in the same level of safety feature because both of them have some disadvantages with regard to Northern Cyprus' environmental conditions, for example the buildings total weight can be reduced by using steel, and therefore it is safer during natural disasters such as earthquakes. But steel is very week with fire and corrosion. In conclusion, as Table 16 shows in this research, the total evaluation rate of steel as a structural beams and columns material is 25, while the total evaluation rate of reinforced concrete is just 17, in context of some of the main features of sustainability.

Table 16. Result of Evaluations between Reinforced Concrete and Steel in Context of features of Sustainability with Regard to Northern Cyprus Conditions (Proposed by author)

Features of Sustainability	Reinforced concrete	Steel
Recyclability	1	3
Embodied Energy Reduction	3	2
Reusability	1	3
Waste Reduction Measures	1	3
Use of Local Materials	2	1
Low Life-Cycle Construction Cost	1	2
Durability	3	1
Pollution Prevention Measures in Construction	1	3
Healthy Materials	1	2
Adaptability	1	3
Safety	2	2
Total Rate	17	25

Note: Low: 1, Medium: 2, High: 3

Chapter 4

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

In this research, the comparison of evaluation results showed sustainability should be considered in building materials to succeed in outcomes while selecting building materials. Likewise, the main aim of this study was to compare sustainability between reinforced concrete as a widely using structural material and steel as an alternative structural building material in Northern Cyprus construction sector to find out which one is more sustainable structural material.

Generally, this study was a comparison of sustainability between reinforced concrete and steel, in terms of some of the main important sustainability features. By consideration to the results of evaluations, the sustainability of steel as a building material is more than reinforced concrete to use in the Northern Cyprus construction sector. The cause for this fact is, the total rate that came from this thesis's evaluations show that steel as a structural beams and columns system material is more sustainable than reinforced concrete (see Table 16). Consequently, in concern to use reinforced concrete as a generally used structural building material in present construction sector, it is important to change a new structural material like steel for applying in building construction in the industry.

With regard to the evaluations results of this thesis, steel is superior to reinforced concrete in context of the most features of sustainability. Steel is classified as a sustainable structural material by consideration to its properties. Therefore, attention to the use of steel as an alternative material is a very important issue and it is intended to play a substantial role in helping the construction sector to achieve sustainability.

Steel is classified as a high recyclable building material in the construction sector. It can be recycled without loss of its properties over and over again. Also, it can be decreasing construction waste in landfills and preserving natural resources, therefore reducing two main problems in the building construction industry. The Prefabrication of steel components provide a clearer and safer working and decrease the pollution and noise on the building construction site. Moreover, construction waste is reduced to a lowest and most of the waste is recyclable. The components of steel can be reused and they easily answer to any changes.

The lack of consideration of sustainability in building materials is a main reason of why alternative material is not used more frequently. Additionally, Whit regard to steel, the lack of steel production and special steel construction workman ships are another reasons that why steel is not considered as a structural building material in Northern Cyprus construction sector. Therefore, as this research shows, it is necessary to consider alternative materials to achieve sustainability. Therefore, to better understand how steel is more sustainable than reinforced concrete, the table below is classified some of the important factors that make steel a sustainable building material (see Table 17).

Table 17. Important factors in the sustainability of steel (Proposed by author)

Sustainability Aspects	Main Advantages
Environment	• Steel as a recyclable and reusable material can be reduction of use of raw material and this leads to source efficiency. And also reduction in waste generation. • Dust and pollution can be reduced by using steel with regard to its properties and construction style.
Economy	• The use of steel construction materials may speed up the construction process of structures which leads to savings in the total cost of the project. • Steel is lighter than reinforced concrete, extra weight will increase the total cost of construction. • Steel structural material is to be able to make and changes easier therefore it can be reduced the cost of maintenance.
Social	• Lighter and flexible structural material has a higher efficiency relating to adaptability, therefore it has potential to answer of any human future needs. • With regard to steel construction style and its properties which classified as a fabricated construction method, steel has less health hazard impacts on the construction workers and engineers in the construction site.

Consequently, this thesis could also be useful for the future researchers who are willing to study sustainability of building material related issues. The progress and promotion of using steel in building construction in Northern Cyprus will lead the country forward to reach sustainability and development. Therefore, in order to achievement sustainability in Northern Cyprus building construction sector, the recommendation above must be considered.

4.2 Recommendations

As aforementioned, the lack of consideration of sustainability in building materials sector is one of the main reasons of contributing to less frequent use of alternative materials in Northern Cyprus building construction sector. Additionally, there can be other reasons for this issue, including: lack of any steel production and steel construction workman ships. Therefore, it is clear that local architects and constructors have to be skilled on how to consider alternative structural materials like steel. There is also a need to make sure that the future building engineers and architects will carry courses on sustainability and alternative building materials in construction sector, hence they could grow themselves in knowledgeable about construction sector.

By consideration the reasons above it is difficult to use steel as a structural material instead reinforced concrete in Northern Cyprus building construction sector. However, it can be useful to consider composite system to construct buildings slab floor components. It means that slab system can be mixed half steel and half concert. This system can improve sustainability capacity of building structure. Additionally, with regard to sustainable benefits of recyclability at least it can be useful to consider making facilities to recycle building materials that come from demolition of the sites in Northern Cyprus. The preceding suggestions are not beyond scope of this thesis and are suggested as recommendations for future research.

In general, conferences and seminars can be useful and be reliable sources for the architects, constructors and specialists in the construction sector, and also it can assist them to be up-date with new building construction materials. It is highly

important that appropriate conferences and seminars be prepared to growth the awareness of specialists in construction sector to achieve sustainability. The research showed the importance of the role of building materials on our environment, economy and society. Therefore, this study has tried to be aware about the benefits of sustainability of building materials also. Architects and constructors have to consider the conditions in their own region to succeed in their design in constructing a building. Additionally, the research showed that building materials are playing significant roles to achieve sustainability.

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