Sustainability and Steel Housing in North Cyprus and Mediterranean Region

Alireza Afshar Ghotli

Submitted to the
Civil Engineering Department
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
September 2009
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Elvan Yılmaz
Director (a)

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

Asst. Prof. Dr. Huriye Bilsel
Chair, Department of Civil Engineering

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 Arts in Banking and Finance.

Asst. Prof. Dr. Murude Celikag
Supervisor

Examining Committee

---

1. Asst. Prof. Dr. Giray Ozay ____________________

2. Asst. Prof. Dr. Isaac Lerner ____________________

3. Asst. Prof. Dr. Murude Celikag ____________________

ABSTRACT

The accelerated deterioration of the human environment and natural resources and the serious consequences on economic and social developments are enough reasons to believe that sustainable development (SD) is the most important and adequate action to overcome these problems. Sustainable buildings are extremely effective on the reduction of the causes of global warming, dangerous environmental impacts and the problems associated with the economical growth fluctuations. The characteristics of SD in building industry, structural and architectural design, by considering the Leadership in Energy and Environmental Design (LEED) statements and Green Building Rating System, are investigated.

The critical environmental impacts in the Mediterranean region and specifically in North Cyprus and possible practical solutions for overcoming such problems are also discussed. This attempt is in line with the consideration of sustainable developments to reveal modification on economic, environmental and social safety in Northern Cyprus.

This research provides a general idea about issues of sustainability in structural and architectural, design, construction, utilization and end of the building structure life with the integration of the building with environment by an in-depth comparison between steel and reinforced concrete (RC) structures.

The contribution of four sustainable building characteristics, structural modeling, architectural plan and questionnaire on sustainable building in North Cyprus relating to appraisal of RC and steel structural material is discussed. In addition, the benefits of sustainable building and the necessary urgent actions to be taken to achieve it are suggested.

Following the general investigation regarding the sustainability issues in the building industry of North Cyprus and the Mediterranean region, a case study comparing a building with RC versus a structural steel alternative was carried out to demonstrate which framing material provides a more sustainable building. As a result of this comparison between a RC and steel framed structure, it was revealed that the **steel framed building** is **more sustainable** and **more economical** for construction. A steel framed structure satisfies the critical issues relating to **sustainable building,** which are **sustainable design, sustainable construction, sustainable utilization and sustainable end of life,** more than the RC framed building.

Keywords: Sustainability; Sustainable Development; Sustainable Housing; RC Structure, Steel Structure; Recycling; Solid Waste Material; North Cyprus

ÖZET

Sürdürülebilir gelişme, süratle kötüleşmekte olan insan çevresinin, doğal kaynakların ve bunun getirdiği olumsuz ekonomik ve sosyal gelişimlerinin üstesinden gelebilecek en önemli olgudur. Bu araştırmada, Yeşil Binaların Değerlendirme Kriterleri, Enerji ve Çevre Tasarımında Liderlik sistemi göz önünde tutularak yapı endüstrisinde yapı ve mimarlık tasarımında sürdürülebilir gelişme incelenmiştir.

Akdeniz bölgesinde ve özellikle Kuzey Kıbrıs'ta olası kritik çevre etkileri ve bunları çözmek için kullanılabilecek olası pratik çözümler tartışılmıştır.

Bu araştırma yapısal ve mimari tasarım, inşaa kullanımı ve bina yaşam sonunun bina çevresi ile entegrasyonunun genel anlamda sürdürülebilirliliğini betonarme ve çelik çerçeve yapıların detaylı karşılaştırılması ile verilmiştir.

Dört sürdürülebilir yapı karakteristiğinin yapı modelleme, mimari plan ve betonarme ve çelik malzemelerinin değerlendirilmesi ile ilgili KKTC'de yapılan sürdürülebilir yapı anketine olan katkısı tartışılmıştır. Buna ek olarak, sürdürülebilir binaların önemi faydaları ve bunların elde edilmesi için acilen yapılması gerekenler önerilmiştir.

Sürdürülebilirlik konusu ile ilgili genel olarak KKTC'de ve Akdeniz bölgesinde yapı endüstrisinde yapılan incelemeler sonucu yapılan örnek çalışmada bir binanın betonarme veya yapısal çelik malzeme kullanımı alternatifleri karşılaştırılmış ve hangi malzemenin

daha sürdürülebilir bir bina oluşturduğu incelenmiştir. Bu karşılaştırma sonucunda çelik çerçeve binaların daha sürdürülebilir ve ekonomik olduğu ortaya çıkmıştır.

ACKNOWLEDGEMENT

I am heartily thankful to my supervisor Asst. Prof. Dr. Murude Celikag for her encouragement, supervision and support from the start to the concluding level which enabled me to develop a good understanding of the subject.

I would like to thank the jury members of my thesis defense for their constructive comments on this thesis. I gratefully acknowledge the chair of Civil Engineering department Asst. Prof. Dr. Huriye Bilsel.

Also special thanks to my parents and thoughtful wife, Maryam for their continuous support.

Finally, I offer my regards and blessings to all of those who supported me in any respect throughout the hard work towards this MSc research and preparation of the thesis.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Sustainability

Increase in the human consumption of resources was a consequence of the industrial revolution, progressed in the early 20th century and resulted in the need to look closely into the matter of Ecology. During 1930s economists began the development of a non-renewable resources management model (Hotelling's rule) and the sustainability of economic prosperity in non-renewable sources [1].

Many vital concepts discovered by scientists during the initial investigation on sustainability which was aimed at approving Ecology as a general scientific discipline. These concepts included:

> *The interconnectedness of all living systems in a single living planetary system, the biosphere; the importance of natural cycles (of water, nutrients and other chemicals, materials, waste); and the passage of energy through trophic levels of living systems* [1].

Environmentalism was explored in the middle of 20th century. After World War II and the great depression in 1950s, the developed world was at the beginning of a new season for intensification growth. Environmental movement convention indicates that "there were environmental costs associated with the many material benefits that were now being enjoyed" [1].

The late 20th century was facing environmental problems that were growing into a global scale. As a result of the 1973 and 1979 energy crises, dependency on a non-renewable resource focused attention on the sustainable development in the global community; at the same time President Carter called on Americans to "Conserve energy. Eliminate waste". To live sustainably, the Earth's resources must be used at a rate at which they can be replenished [1].

An influential publication from the International Union for Conservation of Nature in 1980 which named **World Conservation Strategy**, and then followed in 1982 by its **World Charter for Nature**, remarked that there is a serious warning of decay of ecosystem for our planet.

The United Nation's World Commission on Environment and Development (the Brundtland Commission) made suggestions in relation to the conflict between the environment and development. Indeed the Commission suggested that "development was acceptable, but must be sustainable development that would meet the needs of the poor, but not worsen environmental problems" [1]. They pointed out that during the last 45 years with acceleration of population growth and individual consumption, demands of humanity on the planet has approximately, more than doubled.

> *In 1961, almost all countries in the world had more than enough capacity to meet their own demand; by 2005, the situation had changed radically, with many countries able to meet their needs only by importing resources from other nations [1].*

Sustainable living emerged due to the perception of public understanding of the importance of recycling and renewable energies at this period of time. Wind turbines, photovoltaic and hydroelectricity were the main sources that helped in the development of renewable energy sources in the 1970's and 80's.The construction of the first large-scale solar and wind power plants took place during the 1980's and 90's. Soon after the increase in public awareness of sustainability issues, implementation of small-scale sustainability projects from local and state governments in developing countries occurred [1].

Since the 1980s the idea of human sustainability has become increasingly associated with the integration of economic, social and environmental spheres [2].

In recent years academic articles and public discussions have followed a certain way to interpret the word sustainability with reference to how long human ecological systems can be expected to be usefully productive. They remarked that, in the past human societies have died out, sometimes as a result of their own growth and its associated impacts on ecological support systems. Modern industrial society, which continues to grow in an intricately huge scale, in part reflects this issue.

The suggested preference would be for systems to be productive indefinitely which is to be sustainable. Coconino Community College Arizona State stated that “sustainable development would be the development of environmentally friendly, economic and safe systems that last indefinitely [3]. A part of this statement relates to sustainability of natural ecosystems life cycles and described as other-than-mankind, but the greatest emphasis has been on human life and manmade problems, such as climate change, or the progressive depletion of fossil fuel reserves by humans.

1.2 Objective

The accelerating deterioration of the human environment and natural resources and the serious consequences on economic and social developments, provides enough evidences to accept that sustainable development is the most appropriate action to overcome this important crisis. However SD, which implies meeting the needs of the present without compromising the ability of future generations to meet their own needs, should become a central guiding principle of governments, private institutions, organizations and enterprises.

This research is based on a general review of the definition, appearance and causes of the current interest in sustainability. Furthermore, functionality and the influence of SD in versus human activities including the Building Industry will be discussed.

As a result the significant care for sustainable buildings includes the reduction of global warming causes, dangerous environmental impacts and the leveling of economic growth fluctuations.

1.3 Outline

Chapter 2 provides a discussion of sustainability, its history and background with regard to sustainable development (SD) fundamentals, aims of SD and the rate of success in related achievements.

In chapter 3 the characteristics of SD in the building industry as well as structural and architectural design is discussed in terms of the Leadership in Energy and Environmental Design (LEED) statements and Green Building Rating System.

Chapter 4 reveals the current and future conditions of Northern Cyprus facing the three sustainability fundamentals namely, environmental, social and economic.

The structural and architectural aspects of reinforced concrete and structural steel and their degree of sustainability are discussed in chapter 5. Indeed the aim was to go through the parameters that are effective in building construction and design to satisfy the sustainability fundamentals.

The structural and architectural comparison between steel and RC is also investigated in chapter 6. In fact the two materials are evaluated under the framework and measures of sustainable building. As a result the output of simulated models for each material and sustainable building measures will be introduced to identify which building material is more sustainable material, in the case of building industry.

Consequently Chapter 7 provides the benefits of sustainable building and the necessary urgent suggestions for action that must be taken due to this study.

CHAPTER 2

SUSTAINABILITY; A SHORT HISTORY

2.1 History of Sustainability

2.1.1 What is Sustainability?

Is there a need to intervene to protect the environment, to reduce social cost and vulnerability from human society?

The term “sustainability” has already proven to be useful for human society and the planet as well. Sustainability is the discussion of how to make human life safer with economic systems lasting longer and having less impact on ecological systems. At this stage it makes the discussion more meaningful to give different definitions and interpretations for sustainability.

- The ability to maintain balance of a certain process or state in any system [1].
- An investment in a system of human living, which should be viable on an ongoing basis in terms of providing life quality for all individuals of sentient species and preserves natural ecosystems [4].
- Capability of being maintained at a steady level without exhausting natural resources or causing severe ecological damage [5].
- Being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged [3].

- Sustainability is related to the quality of life in a community whether the economic, social and environmental systems that make up the community are providing a healthy, productive and meaningful life for all community residents, present and future [6].

In general, it is noted that sustainable development goes further than economic growth matter in order to provide requirements that preserve aspects of environmental and social viability.

One of the first and most often cited definitions of sustainability is the one created by the Brundtland Commission, led by the former Norwegian Prime Minister Gro Harlem Brundtland. The Commission defined the sustainable development as “to meet the needs of the present without compromising the ability of future generations to meet their own needs” [6].

Coconino Community College in Arizona State cited The Brundtland definition (WCED, 1987) in order to put the initial steps in the way of preserving future generations.

> *Thus implicitly argues for the rights of future generations to raw materials and vital ecosystem services to be taken into account in decision making, and is in the category of philosophical statements sometimes called "extension theories," In this case, usufruct rights to ecological goods and services are extended to future generations [3].*

In addition, Coconino Community College made a modification on the interpretation of the topic of sustainability, which "addressed to being more sustainable or less sustainable". For instance energy-saving compact fluorescent light bulbs might be considered more sustainable than incandescent ones, and so on. They also give some information on moving towards sustainability or away from it [3]. Sustainability advocates would argue that this kind of debate helps to inform about negative human impacts on the human environment and the Earth as well.

Therefore, this definition accounts for human economic systems so that the sustainable system will be expected to last for a very long time; by definition, indefinitely, and will therefore be around for future generations to make use of, should they choose to do so. By definition those systems that are not sustainable, will not last as long and will be of less or no use in future generations, and may harm other systems that future generation will need.

2.2 Sustainable Development (SD)

2.2.1 Aim of Sustainable Development

The aim of Sustainable Development is not limited to the traditional implementation, such as, planting trees, recycling and cleaning up to protect environment. It also deals with promoting and supporting the economy to achieve a healthy community. A recent survey on sustainable development, undertaken by the UK Government, concluded 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" [7].

Furthermore, the World Commission on Environment and Development (WCED) in a report titled **our common future** published in 1987 introduced current and future generation needs with key concepts:

> *The concept of needs in particular the essential needs of the world's poor, to which overriding priority should be given; and, the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs [8].*

The meaning of sustainable development differs widely in its application. Sustainable development is not a new idea. Many cultures over the course of human history have recognized the need for harmony between the environment, society and economy.

According to sustainable measures [9], the aims of sustainable development defined as "to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future". In the past our present concerns were short term; econometric and technocratic. The holistic approach which incorporates the future in the present is a key dimension of an ecological consciousness. Ecology actions (present) have consequences (future).

The purpose of sustainable development stated as being focused on improving the quality of life for all of the Earth's citizens without increasing utilization of natural resources beyond capacity of the environment to supply them indefinitely by considering economic influences. It should be kept in mind that utilizing natural recourses does not mean destroying the natural environment. It requires excellent understandings that actions have consequences and we must find innovative ways to change institutional structures and influence individual behavior; to take action, change destructive policies and practices at all levels, from the individual to the international.

2.2.2 Illustration of Sustainable Development

The field of sustainable development conceptually embraces three components:

- Environmental
- Social
- Economic

Three elements of sustainable development: environment, society and economy are diagramed as three intersected circles (Figure 2.1).

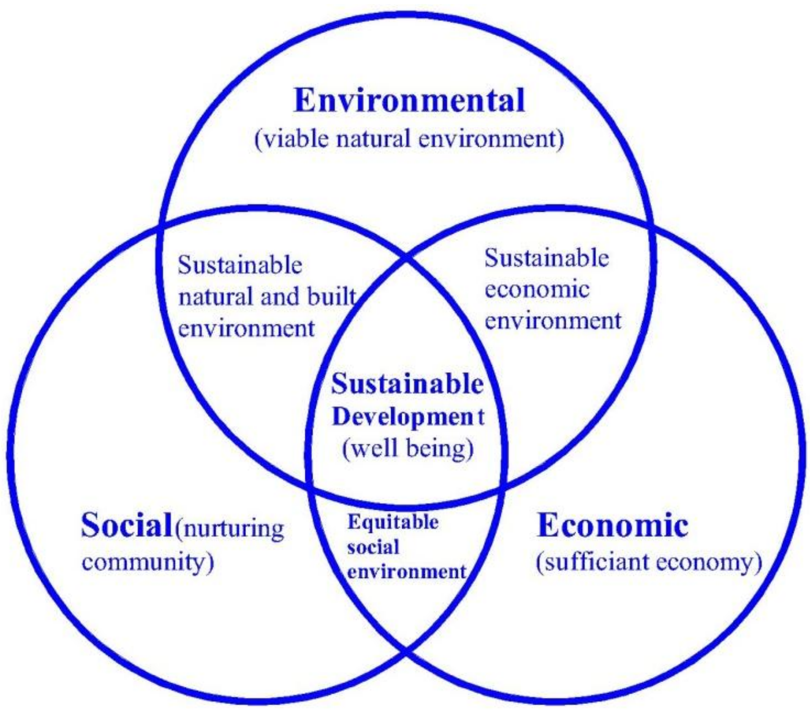

Figure 2.1: Three intersected circles of Sustainable Development Fundamentals

As Figure 2.2 illustrates, the economy completely exists within the society, because all parts of the human economy require interaction among the people. Society, in turn, exists entirely within the environment. Finally, the environment surrounds society.

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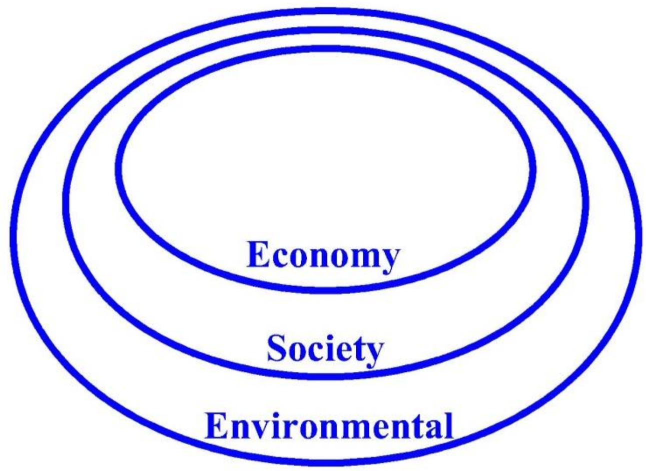

Figure 2.2: Three circles of Sustainable Development

Sustainable Measures [6] believe that "at an earlier point in human history, the environment largely determined the shape of human society. Nowadays, human activity is reshaping the environment at an ever-increasing rate". In co- creative dialectic; we shaped our environment and in turn our environment shapes us. Therefore those parts of the environment which are affected by human activity are getting wider all the time. Also society can never be larger than the environment, because people need food, water and air to survive. Our environments are not natural but cultural. Culture shaped the concepts and awareness of "Nature". Cultural Environment embodies social and natural contexts. This environment also includes all human infrastructures; cities, transportation systems and major institutions. More clearly, when our economy and society can continue to exist without demolishing the natural environment, then all individual, community, national, and global activities are satisfying adequate levels of quality to achieve sustainability.

2.2.3 Why Sustainable Development?

During the last few centuries, across the world, interpretation of sustainable development has often resulted in a conflict between the three main elements of Sustainable Development (Economic, Environmental and Social). In fact in a survey undertaken by the UK Government [7] it was pointed out that pollution and the wasteful use of resources are as a result of economic growth upon the environment. As a result the affected environment has direct influence on climate change, running out of vital energy sources and the quality of life of people with asthma. In addition, benefits gained from the development in the past, were only enjoyed by the minority of people across the world and the majority of people have only suffered from its side effects.

Indeed the balance between the three elements; the Economy, the Environment and the Society has superiority over the aforementioned ideas. One should be aware that sustainability is not only the quality of life, but it is also about understanding the interaction among the social, economic, and environmental parts of a development and achieving balance among them. Quality of life can be under load in terms of SD, if we notice that the environment is fundamentally a human construct, dependent upon vast technological, infrastructural systems. These systems need to be harmonized to maintain quality of life. Simultaneously, we need to use resources more efficiently and increase prosperity in a reasonable and more balanced way across the globe.

2.2.4 Sustainable Development Success Rate and Achievement

Sustainable measure [6] indicates that in each sustainable community some key questions should be asked. For instance: “Are we using this resource faster than it can be renewed?” and “Are we enhancing the social and human capital upon which our community depends?” These are big questions regarding a revolution in the education, IT and digital age.

Since 1980’s we have been faced by accelerated growth of sustainable development. In 1990’s sustainable measure focused on creation and expansion issues of sustainable development.

In order to achieve sustainable development based on the Brundtland Report the leaders at Earth Summit agreed upon critical issues, such as, climate change, desertification and deforestation in 1992. Therefore, Agenda 21 was drafted as the work plan for environment and development issues.

The **Environmental Planning Issue No. 26, November 2002** indicated that “During the preparatory process for the World Summit on Sustainable Development (Johannesburg 2002), it became clear that the search is on for mechanisms to deliver sustainable development”.

National sustainable development strategies (NSDSs) suggested a documentary mechanism for achieving more successes regarding to this matter [10]. A wide variety of groups in different levels of business or municipal governments as well as international organizations (e.g. The World Bank) adopted the concept of development; in addition they offered their own specific descriptions for sustainable developments [6].

Therefore, in order to achieve sustainable development, we are faced with some general initial measures. Sustainable Measure for sustainable development requires certain measures. These are suggested below.

a) Measure the types of material being used (percent renewable vs. non-renewable, percent recycled vs. percent not recycled) and the rate at which it is being used. One cannot use renewable resources faster than they can be renewed (includes energy being used both in production and in transporting workers, raw materials, and finished products).
b) Measure the amount and type of emissions being generated and the rate at which they are being emitted compared to the ability of the surrounding ecosystems to absorb them without harm.
c) Measure the rate at which workers are allowed or encouraged to develop new skills.
d) Measure the amount by which the facility benefits the community around it, the community around the source of its raw materials and the community that is the destination for the product and for the disposal of the product.

The Table 2.1 gives a brief general evaluation measurement in the way of sustainable development recognition [1].

Thus by referring to aforementioned measures to achieve sustainable development, it can be stated that there is a need for adequate education, information and project-analysis assessment due to environmental impact and pointing out investment incentives policies. The interpretation of sustainability and functionality of sustainable development within society indicates that we need to keep our planet in maximum welfare protection condition for future generation.

Table 2.1: General evaluation measurement of sustainable development recognition

Consumption of renewable resources	**State of environment**	**Sustainability**
More than nature's ability to replenish	Environmental degradation	Not sustainable
Equal to nature's ability to replenish	Environmental equilibrium	Steady-state economy
Less than nature's ability to replenish	Environmental renewal	Sustainable development

Although the focus is on achieving sustainable development in this matter, the restructuring to make development more sustainable will also be emphasized.

2.3 Restructuring Development and Economic Growth for Greater Sustainability

In terms of restructuring development Munasinghe, M the author of **Development and Growth for Greater Sustainability** believes that without protecting valuable resources, such as air, forest, soil and water sustainable development will not be achieved; not just for a few years, but for many decades. Accordingly, the impacts on the environment and the way towards sustainable development are reduced. He also illustrated changes (Figure 2.3) in the structure of economic growth that exposes environmental risk versus development level [11].

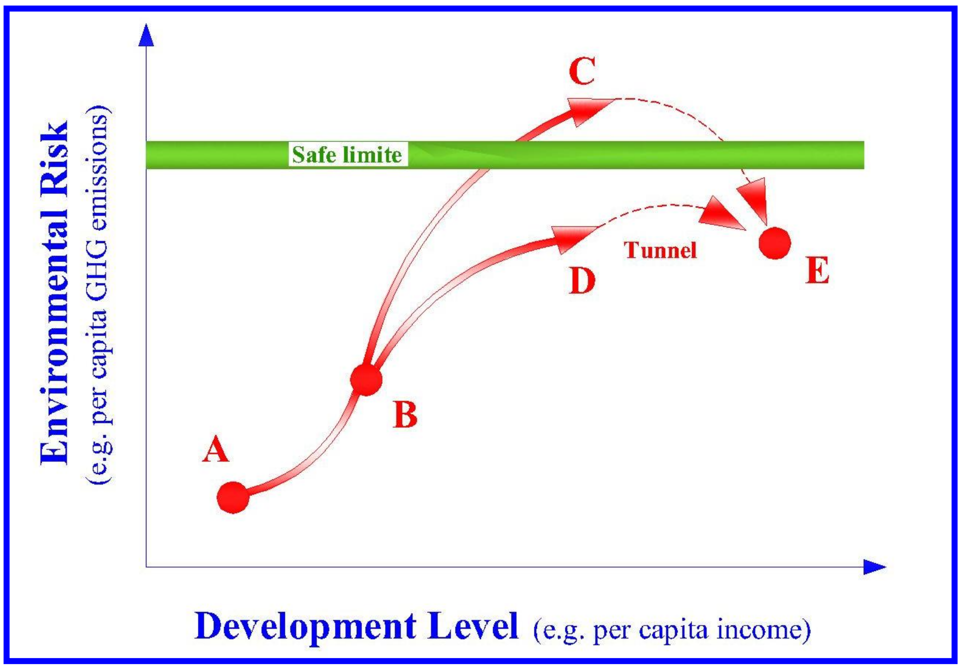

Figure 2.3: Changing the structure of economic growth

Figure 2.3 shows environmental risks versus development level. [Source: adapted from Munasinghe 1995a]. In this figure he aimed to express the importance of changing the structure of development and growth. Indeed the author pointed out "how environmental risk in a country (e.g., represented by greenhouse gas (GHG) emissions per capita) might vary with its level of development (e.g., measured by gross national product (GNP) per capita)". Most of the developing countries may be at point B. Whilst during early stages, along AB; one would expect carbon emission to rise more rapidly and along BC when per capita incomes are higher than the level being off.

In fact industrialized nations are at point C. Ideally, industrial countries that exceed safe limits should do more to protect environment and follow the curve to reach point E. Munasinghe proposes that developed countries should remember the past experiences of the industrialized world and adopt policies to reach point E by following the BDE curve. This means that achieving sustainability with minimum impact and damage on environment like climate change or biodiversity loss which is irreversible.

CHAPTER 3

SUSTAINABLE DEVELOPMENT OF BUILDING STRUCTURES

3.1 Back ground

The Agenda 21 at the 1992 Earth Summit stated that strategic planning for sustainable development is based on “assessing what has worked well and where there have been difficulties”. As a result, it is necessary to identify the steps needed to improve processes, the kinds of monitoring systems required to continue to make sustainable development more reliable.

The Canadian Society of Civil Engineering (CSCE-SD) document on 22 January 2007 discussed the guidelines of sustainable development [12]. The guidelines were encouraging the Civil Engineering community to practice their profession in the most sustainable manner possible. This document was focused on sustainability and life cycle appraisal referring to the planning, design and operation of civil infrastructure. Thereby, development of new technologies and management practices for minimizing the use of energy, non-renewable resources and production of waste materials is required.

Although, Civil Engineering works made life more comfortable, accessible and healthy for all of us, but the effects on economics and standard of living and environmental infrastructures are unavoidable. Eventually the concerted efforts of governments, the private sector and civil societies working together in partnership are effective initial requirements to achieve sustainable development goals.

In terms of the definition of sustainability the CSCE expressed that “sustainability is thus a social concept (inter-generational), an environmental concept (conservation and protection) and an economic concept (living on the earth’s interest)” [12].

An international protocol “Engineering a Sustainable Future for the Planet” was recently signed (July 2006) among the CSCE, the American Society of Civil Engineers and the Institution of Civil Engineers (UK). This protocol involves a major commitment to sustainability by the Civil Engineering community [12].

Some of the global issues emerged recently are climate change, preservation and enhancement of the environment, human health effects, loss of biodiversity, and the consequences of fossil fuel shortages in the future. As a result, it is more important than ever, that civil engineers can guide the development process to achieve sustainability.

Therefore, the effectiveness of civil engineering, architectural profession and government sector towards sustainability in housing will come up soon. In addition some other related definitions, such as; sustainable building structure, sustainable design, sustainable architecture, and LEED will be discussed.

3.2 What is a Sustainable Building Structure?

The comprehensive argument regarding the description of sustainability, facts and needs of sustainable development within human society and the maximum welfare for future at any level, require us to have a better understanding of **sustainable building structure**. This leads us to an efficient, maintainable and adoptable structure in the housing construction sector.

Obviously, the building structural system does not have as dramatic effect on as the energy efficiency that is achieved through decreased heating, cooling and lighting demands, but it has direct effect on sustainability [13]. Therefore, in the case of making a decision while dealing with a structural system one should be more discriminating.

3.3 Energy and Environmental Design

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), provides a suite of standards for environmentally sustainable construction. "Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in 50 U.S. States and 30 countries covering 1.062 billion square feet (99 km^2) of development area"[14]. This indicates that they have passed the accreditation exam given by the Green Building Certification Institute (a third-party organization that handles accreditation for the USGBC). Different versions of the rating system are available for specific project types like:

- LEED for New Construction: New construction and major renovations (the most commonly applied-for LEED certification),
- LEED for Existing Buildings: Existing buildings seeking LEED certification,
- LEED for Commercial Interiors: Commercial interior fit outs by tenants,
- LEED for Core and Shell: Core-and-shell projects (total building minus tenant fit out)
- LEED for Homes: Homes
- LEED for Neighborhood Development: Neighborhood development
- LEED for Schools: Recognizes the unique nature of the design and construction of K-12 schools
- LEED for Retail: Consists of two rating systems. One is based on New Construction and Major Renovations version 2.2. The other track is based on LEED for Commercial Interiors version 2.0

The LEED rating system addressed six major areas and specific separate scale of points for each one and containers factors:

1. Sustainable sites (14 points)
2. Water efficiency (5 points)
3. Energy and atmosphere (17 points)
4. Materials and resources (13 points)
5. Indoor environmental quality (15 points)
6. Innovation and design process (5 points)

Different LEED versions have varied scoring systems in the six major categories listed above. In LEED v2.2 for new construction and major renovations for commercial buildings there are 69 possible points and buildings can qualify for four levels of certification:

- **Certified** - 26-32 points
- **Silver** - 33-38 points
- **Gold** - 39-51 points
- **Platinum** - 52-69 points

3.4 Sustainable Design

"Sustainable design is aimed at reducing the environmental and health impacts caused by the construction and operation of the buildings. It focuses on energy efficiency, indoor environmental quality, material selection, site planning, resource efficiency, and water used in order to reduce the associated negative impacts. Materials used in the building industry make an enormous impact on the environment due to the acquisition of materials and resources, energy used, and waste generated during the production, use and disposal of building materials. Many materials, emitting hazardous substances gas into the air during installation and sometime long after buildings are occupied. Materials can add long-term cost due to **replacement and maintenance** if not properly selected. In the past, it has been assumed that materials should be new and from virgin sources, placing an unnecessary burden on the environment due to the extraction of resources for material production" [13].

Referring to the above mention description of sustainable design by **Nils V. Ericson, PE,** there is a case study that can be a good example for this issue.

3.5 Case Study (example)

Hamilton Avenue School - Greenwich, CT [13]

Figure 3.1: Sketch of Hamilton Avenue School

Architect: Swanke Hayden Connell Architects, New York, NY

Owner: Town of Greenwich, CT

Description: The Hamilton Avenue Elementary School, currently under construction, is designed to achieve a Silver LEED certification Level. Some of the project components which meet the criteria for LEED certification are as follows:

- Re-use of the original 1938 Building
- Use of geothermal wells for heating/cooling
- Dedicated open space on the site
- **25%-50% recycled content of all building materials (steel frame building)**
- Construction waste management - divert 50% of waste from landfills
- Carbon Dioxide level monitoring sensors in the classrooms

- Displacement ventilation system for increased ventilation effectiveness
- Low-Emitting Adhesives, Sealants, Paints, Carpet
- Day-lighting for 75% of spaces; Views for 90% of spaces

The new construction consists of a two-story, 75,500 square foot (7,015 square meters), school building and a two-story, 2.416 square feet (2,416 square meters) underground parking area. The parking area will have a landscaped roof with the school bus drive and turn around. The section of the original building that was incorporated into the new school has been upgraded to meet current seismic codes. Estimated cost is $29 Million.

Figure 3.2: Structure of Hamilton Avenue School

3.6 Sustainable Architecture

"Is a general term that describes environmentally-conscious design techniques in the field of architecture? Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the **negative environmental impact** of buildings by enhancing efficiency and moderation **in the use of materials, energy,** and **development space** [15]".

To speak of sustainability in architecture means conceiving constructions for the future, not only in terms of the physical durability of the building, but also the durability of the planet and its energy resources. In this case, it seems that sustainability would be based on the introduction of a productive model in which available materials and resources are more efficiently used, rather than squandered or ignored. To speak today of the ecology of a building is, in short, to focus on its capacity to integrate environmental and climatic parameters; and to transform them into qualities of **space, comfort, and form** [16]. Houses are extension of the bodies' homeostasis system for cooling and heating. Houses can use active and passive systems; the latter are more sustainable and incorporate form as a design parameter.

Our homes have to be comfortable, healthy and meet all our varied demands by keeping the future in mind (e.g. thermal walls, wind & light scoops, insulated walls, breezeways, etc). To achieve a sustainable urban design there are some considerations, for instance, design excellence, social well-being and environmental responsibility.

Interaction on integrity of buildings into the existing cities and countryside must be considered. All attempts in these criteria should be made that more and more people have access to housing that is comfortable and healthy both initially and long term.

"The main idea is that the construction methods must comply with the demands of ecology and the preservation of environmental as well as human health [17]".

The concept of building sustainability is responded to different ways by builders, architects, engineers, politicians and citizens. With green buildings, eco-houses and sustainable designs, the main goal is to:

- Reduce the negative effects that the building has for human safety and environment.
- Decrease the amount of energy consumed.
- Decreases the capital and environmental costs.

In an urban development the urbanism, transport, landscape, energy, buildings, environment and citizens are all interrelated and integrated**.**

3.6.1 Criticism on Sustainable Architecture

"Sustainable architecture; it can be argued, **does not rigorously form a part of architecture as a discipline**" [15]. Rather, it is a concern in the building construction industry as a whole, and given the dominance of construction techniques and building subsystems, it should be considered a part of civil engineering as a discipline. Sustainable architecture will be more effectively integrates with architecture at all levels; design, production of drawings, site use, etc. Numerous schools of architecture shun "sustainable architecture" as a part of their curriculum, and it is considered to be a fashionable subject at the moment. A number of architects practicing this type of architecture have been criticized as exploiting a dominant concern in the name of architecture in order to gain reputability and garner profits [15].

Finally, as well as civil engineers the architects should contribute more and more specifically to do the design of any building. As a result by considering the important issues like green building it will be easier than ever for companies to achieve sustainable building design and construction.

CHAPTER 4

IDENTIFYING THE PROBLEMS IN CYPRUS AND IN THE SURROUNDING REGION

4.1 Introduction

In this chapter, the critical environmental impacts in the Mediterranean region and specifically in Northern Cyprus and possible practical solutions for overcoming such problems will be suggested. Indeed, this attempt is in line with the considerations of sustainable developments to reveal modification on economical, environmental and social safety in Northern Cyprus. Finally, in the context of globalization, each country is responsible to protect Earth's safety with the aim of preserving the future.

4.2 Global Warming

Global Warming is related to environmental impact and furthermore with sustainable development. Due to human activities, such as, the indeterminate use of fossil fuels, agriculture, deforestation and industry the earth faces a dangerous increase in temperature. In recent years the scientists pointed out that the earth's average temperature values have been increased by 0.5 degree. Most people did not think that this will have any effect on their lives.

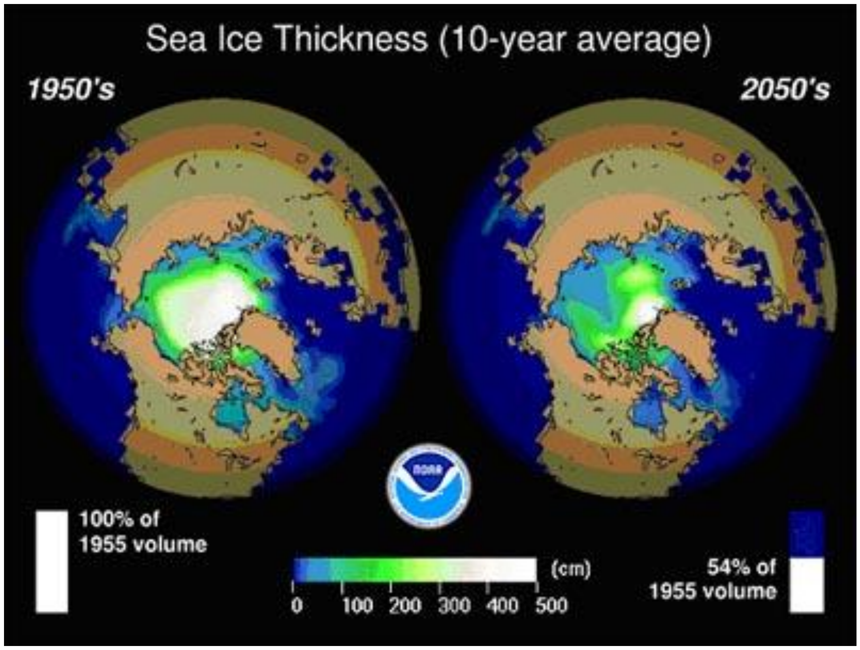

Figure 4.1: Adopted global warming average [18]

However, this very small change, half a degree increase in temperature, is more than enough to melt the ice in poles and therefore has serious effect on ecological balances. Scientists are estimating that if no major decisions are taken regarding the control or elimination of the greenhouse gases the earth's average surface temperature will raise between 1.4 and 5.8 °C between the years 1990 and 2100 [19]. Common greenhouse gases in the Earth’s atmosphere include water vapour, carbon dioxide, methane, nitrous oxide and ozone. Greenhouse gases greatly affect the temperature of the Earth’s surface and without them the earth’s surface would have been, on the average, about 33 °C (59 °F), which is colder than what it is now.

4.3 Global Warming in North Cyprus

North Cyprus is one of the countries affected by global warming. The information given by the Meteorology Department Administrator Mr. Fehmi Oktay [18] indicates that, during the period of 1941-1970, the lowest temperature values in this country were between -1°C and -7°C.

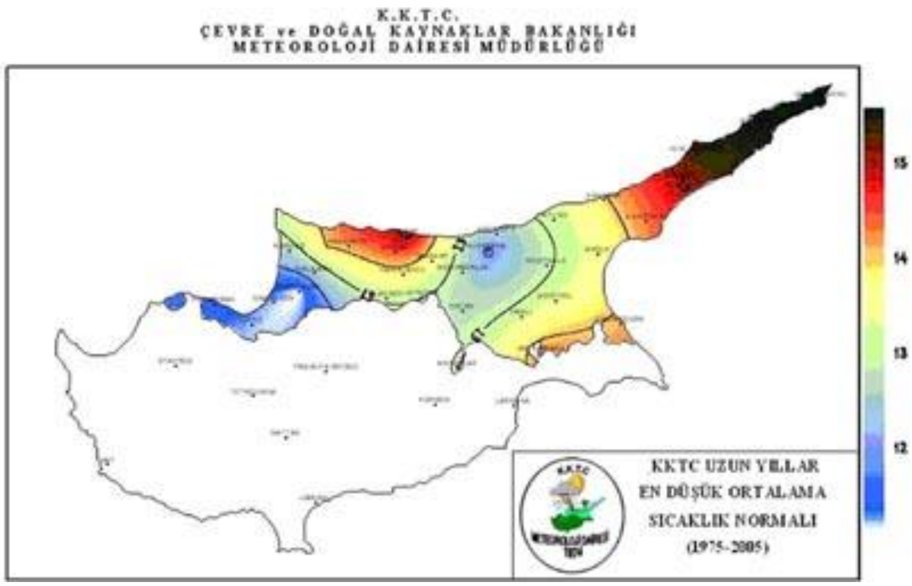

Figure 4.2: The lowest average temperatures (1975-2005)

The lowest temperatures in Northern Cyprus during the period of 1941-1970 were between -1°C and -7°C, but due to global warming the whole world, including North Cyprus and the Middle East are getting warmer. The average values of the lowest temperatures were 12°C to 15°C in 1941-1970, which were approximately between 24°C and 30°C (1975-2005).

Accordingly the recorded highest temperature values were changing between 39°C and 45°C (1941-1970). The hottest place was Middle of Mesarya (Ercan) in July. But, in the period of 1975-2005 the values of the average highest temperatures were approximately

21°C to 27°C. Finally, during the years of 1941-1970 the temperatures were not higher than 45°C. But, during the period of 1975-2005 the temperature reached to 50°C and above.

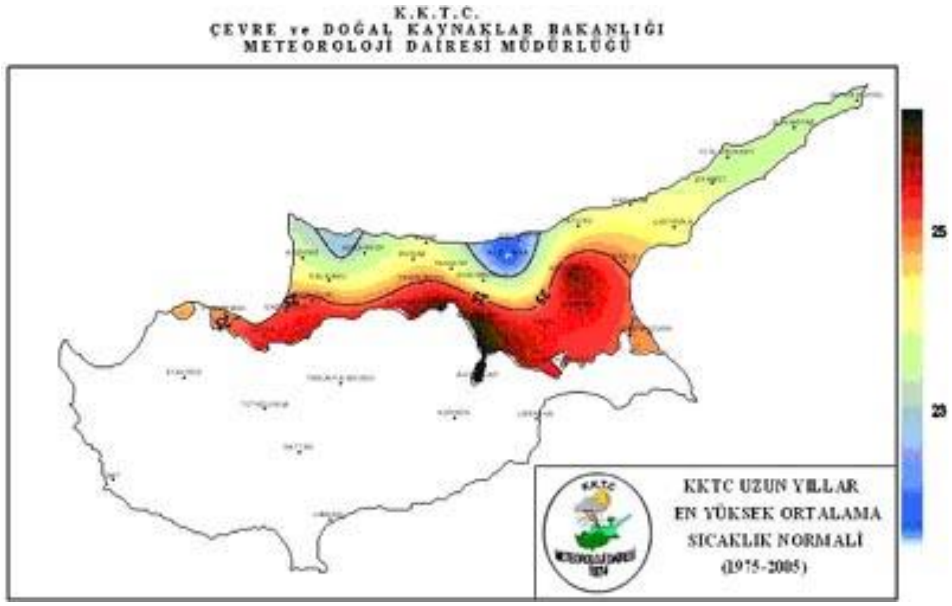

Figure 4.3: The highest average temperature (1975-2005)

Therefore, to stop global warming Northern Cyprus should act with the rest of the world, as part of the global movement to reduce the most dangerous greenhouse gases spreading; such as, CFCs (chlorofluorocarbons), CO (carbon monoxide), CO_2 (carbon dioxide), CH_4 (methane) and N_2O (nitrous oxide).

The following are the suggestions to decrease the spreading of the carbon dioxide gases:

1- Bulbs: to change the standard bulbs to economic bulbs so that75kg carbon dioxide per year can be saved.

2- Less usage of cars: to walk, use bike and public transport more frequently so that 0.75kg carbon dioxide per 2 km can be saved by not using the car.

3- Contribution to recycling: 1200kg carbon dioxide can be saved per year

4- Regular check of wheels: could save up to 4lts of fuel and 10kg of carbon dioxide per year.
5- Usage less hot water: 175kg carbon dioxide can be saved by using less water for shower and laundry.
6- Adjusting the heater: by decreasing the temperature of the heater by 2°C in winter and increasing the air conditioner by 2°C in summer could save up to 1000kg of carbon dioxide per year.
7- Planting more trees: every tree can absorb 1ton of carbon dioxide per year.

The EU adopted an integrated energy and climate change policy in December 2008, including ambitious targets for 2020 [20]. It hopes to set Europe on the right track - towards a sustainable future with a low carbon, energy efficient economy by:

- Cutting greenhouse gases by 20 percent
- Reducing energy consumption by 20 percent through increased energy efficiency
- Meeting 20 percent of our energy needs from renewable sources.

The greenhouse gas emission reduction targets of Kyoto protocol reported that, the global CO_2 emissions are today some 40 percent higher than they were in 1990. It is estimated that in order to limit the average global temperature increase to less than 2°C compared to pre-industrial levels, global greenhouse gas emissions must be reduced to less than 50 percent of 1990 levels by 2050 [21].

4.4 Mediterranean Region

A workshop about Sustainable Waste Management in the Mediterranean Region was prepared by the European University Institute for the 11^{th} Mediterranean research meeting to be held on March 2010. As a result of the workshop the report prepared indicates that "solid waste management is a key task of city councils and municipalities throughout the world in order to keep cities tidy and clean" [22].

Although, solid waste management is highly effective on saving environment and furthermore human health, conscious use of natural resources to obtain materials and use of energy sources should be limited. In one hand solid waste management involves waste prevention, energy saving, reuse, recycling and energy recovery, but on the other hand urban solid waste management demands a well designed mix of policy, administration, corporate social responsibility, business economy, motivation and education of the individual citizen.

"Successful implementation of such management of solid waste then becomes strongly dependent on the local and regional socio-economic and political attributes of the area where the waste is generated, in addition to the traditional collection and treatment technology aspects" [22].

United States and Europe has enhanced the design of many products with the goal of improved recyclability and waste minimization. In some cases, waste management can consume up to 40 percent of the budget of a municipality.

In order to move towards a better management of material resources and improved resource efficiency the revised Waste Framework Directive is indicated three basic concepts; the waste hierarchy, the prevention of waste with consideration of material life-cycle. “The Directive lays down important targets for the recycling of waste for the year 2020: 50 percent for household waste recycling and 70 percent for construction and demolition waste [21].

Global demand for natural resources is growing fast, and will continue to increase due to the growth of the population, which is expected to reach 9 billion people by the year 2050. Measured by the ecological footprint, it is estimated that this would be 30 percent more than the planet can sustain in the long term.

Therefore, taking decisions relating to waste management operations, such as collection, recycling and disposal, lead decision makers to include subsections on the importance of all issues relating to economic, environmental and social safety.

4.5 North Cyprus and the Mediterranean Region

An investigation undertaken by the World Health Forum [23] indicated that 18 countries bordering the Mediterranean Sea have a population of around 350 million out of whom 135 million live in the coastal zone.

Cyprus is the third largest island in the Mediterranean Sea and it is located at 35°N of the equator and 33°E of Greenwich (Figure 4.4). North Cyprus has an area of 3354 Square km and a population of about 300,000.

It is important to note that the electricity utilities of Northern Cyprus are adversely affected by the rising costs of production, high rate of growth and high rate of electricity.

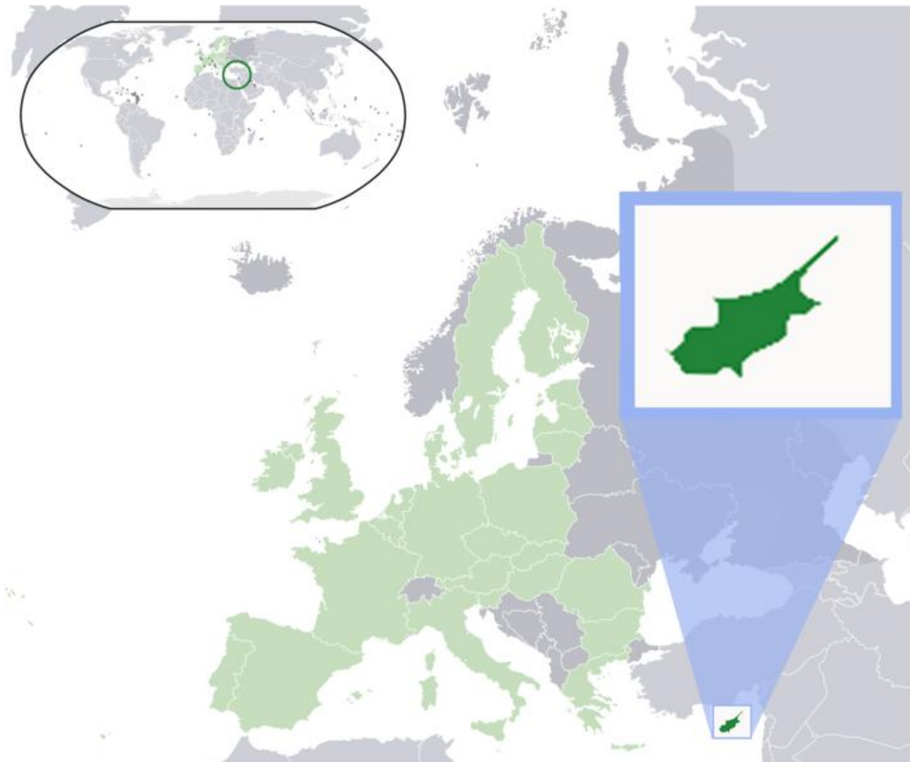

Figure 4.4: Location of Northern Cyprus in the region

The KIB-TEK (Cyprus Turkish Electricity Authority or Türk Elektrik Kurumu) statistics show that a serious consideration is required regarding the uncertain increase in demand, rising cost of fuel, high cost of new investment for extra capacity and environmental constraints. It is important to acknowledge that electricity is produced by burning fuel oil, not natural means (e.g. wind, solar cells, overflow fan houses) and also subsides passive solar conversion of the houses to use wind and sun in North Cyprus.

Figure 4.5: Map of the Northern Cyprus

Unscheduled urban design, inadequate quality of building construction and lack of awareness about sustainable construction and usage of recyclable materials with high insulation capacity are some critical areas that threatens the efficient usage of power in Northern Cyprus.

Although harmful ozone gas in North Cyprus is below the normal limits [18], but levels of other harmful gases such as SO_2, CO, NO_2 in urban areas are between 40-49 percent and in some cases it is even higher. North Cyprus is facing the effects of the SO_2, CO, NO, NO_2, O_3, and in particular the unburned fuel and some other materials from industry. Indeed the power generating utilities, transportation and industry are the main reason of these harmful gases. The North Cyprus Environment Office reported that the:

- Measurements of unburned fuel are not available at present.
- NO_2 levels are higher in the urban areas.
- SO_2 levels are higher near the Power Plant in Teknecik, Alagadi, near Kyrenia, in Northern Cyprus.

Most of the energy used in making products is wasted because we design them in a way that they will be scrapped in a short time [24].

It is important to note that in any development one of the optimum solutions to reduce energy consumption and protect environment, social safety and the economy in the long term, is to make longer lasting products.

4.6 Solid Waste in North Cyprus

The average human use of materials is 45-85 tones each year. There are a number of concepts about waste management which vary in their usage between countries or regions [1]. Some of the most general, widely-used concepts include:

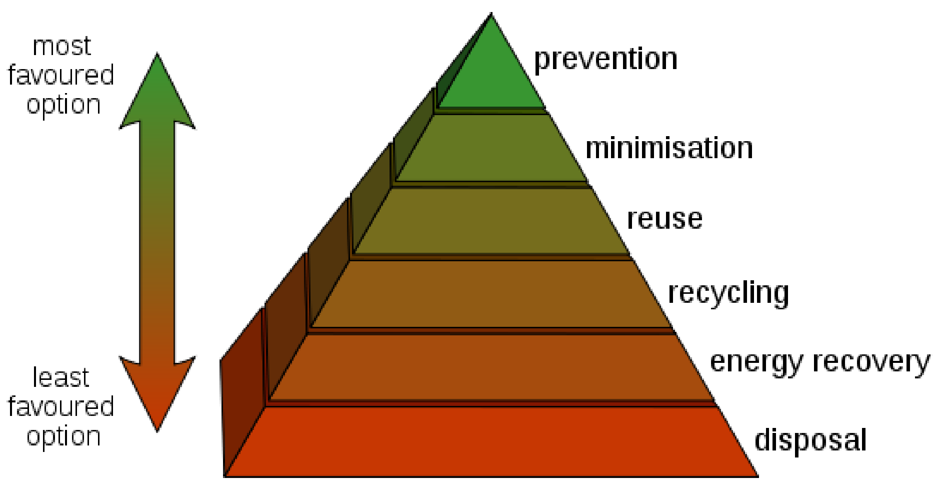

Figure 4.6: The importance of the waste management subsections (Figure Adopted from reference [1]).

The waste hierarchy as indicated in Figure 4.6 has three major themes; reduce, reuse and recycle, which classifies waste management strategies according to their desirability in terms of waste minimization. The aim is to take out the maximum efficient benefits from products and at the same time to reduce the amount of waste generated.

Just like the other countries in the region Northern Cyprus is also faced with the problems of managing waste material. It is obvious from Table 4.3, that the high percentage of total waste material in this country belongs to building construction tasks. It is important to note that the manufacturing of the longer lasting products will not necessarily reduce the solid waste. However, the aim is to make the products more sustainable in accordance with the fundamentals of sustainable development. Currently, it appears that uncontrolled energy consumption and unlimited use of natural sources are taking place.

It is also important to address special waste streams in the solid waste management strategy for the Northern part of Cyprus, including:

- Hazardous industrial waste
- Medical waste
- Old tyres
- Waste oils
- Batteries
- Waste electrical and electronic equipment (WEEE)
- End of life vehicles (ELVs)
- Asbestos wastes
- Construction and demolition waste

Although all these wastes are serious matters in solid waste management in Northern Cyprus, however, in this section the construction and demolition waste is the most critical issue relating to the building sustainability. Therefore, the influences of the construction and demolition waste are discussed in more detail below.

4.6.1 Construction and Demolition Waste

Most construction and demolition waste material is inert, with insignificant leach-ability and pollution content, and this type of waste makes up a large proportion of the total waste generated in the Northern Cyprus. During the future operation of the sanitary landfill, it will be important to keep such inert wastes out of the sanitary landfill, since expensive environmental protection measures are not needed, and it is much more cost-effective to save the landfill space for wastes that could have a potential impact on the environment [21]. Examples of inert construction wastes include:

- Concrete
- Bricks
- Tiles
- Waste glass (without organic binders)
- Ceramics
- Uncontaminated soil and stones

The waste management strategy of the Republic of Northern Cyprus emphasized development of a market for secondary construction materials which will be supported by establishment of technical specifications and quality criteria for secondary construction materials [21].

It is suggested to identify as many options as possible for reuse and recycling of the waste, for example, it could be used as follows:

- Construction projects, such as filling material and foundation.
- Highway projects, road repairs, etc, including access roads to the landfill.

- Rehabilitation of existing disposal sites, as part of the cover material.
- Short-term improvement at disposal sites until they are closed, for example to improve access roads and on-site roads and to rehabilitate parts of the sites.
- Cover material for the sanitary landfill site.
- Reuse of wood from construction projects or use of wood as fuel.

A more detailed inventory and plan will be required for these inert types of waste. In addition, it is essential that this is backed up by new regulations that require construction companies to take the necessary actions to manage, reuse and recycle their construction wastes or deliver them to a storage site before they are used for the above activities. The regulation will only be implemented if there is strengthened monitoring and enforcement [21].

It should be expected that waste generation per capita is going to increase in Northern Cyprus, because of the rise in consumption with the increase in the standards of living. The variation of waste generation in Western European countries is in agreement with this assumption that the waste generation was continuously increased from average 476 kg per capita per year in 1995 to 580 kg per capita per year in 2003 [21].

In 2002, the Republic of Cyprus was producing approximately 0.654 tones of municipal waste per person yearly, and waste production was on the increase with the volume of waste generated in 2002 being 29.2 percent above 1995 levels. Production of municipal waste in the Republic of Cyprus is much higher than in other new EU member states with similar GDP per capita and comparable to more developed member states of

Western Europe. In Northern Cyprus the average of GDP is just over 10 thousand Euros per capita.

Although the solid waste management is one of the critical issues in order to preserve the Northern Cyprus environment in case of building industry the collected waste is either non-recyclable or very low in recyclability [21]. Therefore, the consumption of natural resources is at its maximum rate. Consequently the environmental impact and energy consumption are influencing the safety of the society and the economy.

In building construction, use of recyclable and longer lasting materials is extremely important for the reduction of environmental impact and with the result of a safer atmosphere for human life. The goal is to make our industrial products reusable after their end of life cycle.

Waste cannot be avoided altogether. But reducing the high percentage of waste production, in particular minimizing waste during material production process, period of use and end of its life would be an effective procedure in waste management.

The best waste reduction strategy embraces the three main activities; reduce, reuse and recycle terms. Thereby reusing, recycling or energy recovery would contribute towards overcoming the waste problem. As a result, the medium-term goal is to ensure that only non-recoverable waste and inert waste is accepted in landfills.

The Master Plan on Solid Waste Management in the Turkish Cypriot Community [21] pointed out that the total amount of Construction and demolition, Commercial and Green waste disposed during 8 months of 2006 was 20,019 tones (Table 4.1) and 20,663 tons during the same period of 2007 (Table 4.2). If extrapolated to the whole year, annual per capita generation rate of waste are 276.5 kg in 2006 and 285.4 kg in 2007. The amount of waste is given as construction and demolition 45 percent, commercial 35 percent and green 20 percent.

Among the waste delivered to the landfill by private companies the major part (about 70 percent) is waste of construction and demolition. The remaining 30 percent waste comes from various industrial and slaughter house facilities. Military waste mainly consists of household and similar waste (about 70 percent) and construction/demolition waste (about 30 percent).

Based on the data adopted in Table 4.3, the overall waste production per capita in Northern part of Cyprus is categorized into 6 different generators. Generation of green waste is comparatively low which approximately 5 percent of the total amount. The highest waste average is 487 kg per capita and percentage is 44percent in construction and demolition; there is a direct relation between most of the environmental impacts and the inadequate building construction tasks in this country. The total annual waste generation is 290.8 thousand tons per year (Table 4.4). It is notable that green waste has the lowest amount about 14.9 thousand tones and construction and demolition waste is extremely high when compared to the total of all.

Table 4.1:Waste delivered to Dikmen disposal site by private companies and military, tone in 2006 (Adopted from Master Plan on Solid Waste Management in the Turkish Cypriot Community).

	2006							
	January	February	March	April	May	June	July	August
Private companies	2,483.9	4,492.5	5,392.0	5,193.8	4,832.9	5,503.2	4,193.7	4,394.7
Military	294.3	227.4	410.4	439.6	483.9	228.4	230.0	359.4

Table 4.2:Waste delivered to Dikmen disposal site by private companies and military, tone in 2007 (Adopted from Master Plan on Solid Waste Management in the Turkish Cypriot Community).

	2007							
	January	February	March	April	May	June	July	August
Private companies	2,730.9	4,804.9	6,011.8	5,282.6	276.8	6,862.0	4,425	5,096.6
Military	312.7	213.3	496.2	501.6	791.3	298.9	381	415.1

Table 4.3:Overall evaluated of waste generation in Northern part of Cyprus, kg per capita. (Adopted from Master Plan on Solid Waste Management in the Turkish Cypriot Community)

	Average generation of waste kg /capita per year	**Percentage generation of waste**
Household waste	276.6	25.2
Commercial waste	127.8	11.6
Municipal waste	404.4	36.9
Construction/demolition	**487.0**	**44.4**
Green waste	56.2	5.1
Industrial waste	149.1	13.6
Total	**1,096.8**	**100.0**

Table 4.4: Evaluated annual waste generation in Northern part of Cyprus

Waste type	**Waste Generation, thousand tons per year**
Household waste	73.3
Commercial waste	33.9
Municipal waste	107.2
Construction/demolition waste	**129.1**
Green waste	14.9
Industrial waste	39.5
Total waste generation	**290.8**

4.7 Economic Growth in North Cyprus

The economy of the Turkish Cypriot Community is dominated by the services sector including the public sector, trade, tourism and higher education, with smaller agriculture and light manufacturing sectors. Problems in the banking sector and failure of the foreign currency policy of Turkey started an economic crisis which caused a decrease in investments and public revenues. On the other hand a recession in the economy (2000 and 2001) produced an increase in inflation rate and unemployment. In 2002, the economy has recovered as a result of measures taken in the banking system and finance supplied from Turkey and the hopes for the reunification of the island. The real GNP growth rate during the last ten years (1996-2006) was fluctuating from -5.4 to 15.4 percent. The overall GDP change from 1996 to 2006 corresponded to average growth of 6.1 percent.

In the following three year period, an annual average growth rate of 7 percent is projected by the State Planning Organization to be realized as a result of public sector reform, social security reform and similar transformation projects. The necessity of sustainable tasks in all production process by increasing competitiveness productivity is not avoidable.

The environmental, economical and social fundamentals are faced with hazardous factors in Northern Cyprus. One should note that rather than discussing about these factors in detail, which requires extensive analysis, we just mention the most critical ones below:

- Construction and demolition generated about 44 percent waste (129.1 thousand tons per year).
- Most of the building structures materials in this country are not recycled, approximately 47 percent, and the rest become the land fill.
- Limitations of electricity generation.
- Levels of injurious gases, such as SO_2, CO, NO_2 in urban areas are between 40-49 percent.
- Population growth rate between the years 1996-2006 (0.031percent) is not sustainable and will gradually decrease in the long run.
- The economy of the Turkish Cypriot Community is dominated by the services sector including the public sector, trade, tourism and education, with smaller agriculture and light manufacturing sectors.
- The evaluated municipal waste generation per capita is approximately 400 kg per capita per day. Waste generation per capita is not in line with the increase in the GDP, it is somewhat faster that the GDP.

The use of the recyclable and repairable structural material in building construction tasks will greatly affect the reduction of the land fill material, harmful gases, global warming, energy consumption and natural resources.

The Extended Producer Responsibility (EPR) is a strategy designed to promote the integration of all costs associated with products throughout their life cycle (including end-of-life disposal costs) into the market price of the product [1]. It means that relating to building industry the contractors, the private sector, the government, the civil engineer and architects are required to be responsible for the products after their useful life as well as utilization period.

The Polluter Pays Principle (pp) is a principle where the polluting party pays for the impact caused to the environment [1]. In other words it is required to have the appropriate regulations for the waste generators to pay for the disposal of their waste.

CHAPTER 5

INVESTIGATION OF THE SUSTAINABLIBITY BETWEEN REINFORCED CONCRETE AND STRUCTURAL STEEL

5.1 Introduction

This chapter will detail the general perception of the sustainability for buildings by considering the structural and architectural aspects, concerning with the ecological, economic factors, environmentally friendly elements in buildings and safety for human life. Considering the characteristics of sustainable design and construction mentioned in pervious chapters. It is now appropriate to discuss the characteristics of reinforced concrete and steel structures in four phases. This chapter is aimed to make a clear observation of these two structural materials from the point of view of architectural and civil engineering principles in four phases of sustainable structure:

1. Design
2. Construction
3. Utilization
4. End of life

5.2 Framework of Sustainable Building Evaluation

In general, Sustainability includes environmental, economic and social concerns for achieving a long-lasting building project. In particular, sustainability of building construction is faced with the major health and environmental aspects relating to the life-cycles of all types of buildings. Eventually a building's life-cycle contains production, use and deconstruction divisions. The two most important unavoidable issues are impact of energy consumed and material utilized on the planet.

Indeed "most environmental and economic issues can be affected by the choices made by you and your colleagues working within the construction processes" [25]. However, the social and human safety measures are left to the politicians, governments, civil engineers, planners and architects.

- The economical division in building sustainability considered from two main points of view, the employers and the economic construction sector which is vital for welfare growth and investment of businesses for now and the future.
- The usage of all types of buildings and construction related activities generate more than 40 percent of all the CO_2 (carbon dioxide) emissions. This is equivalent to the utilization of about 40 percent of the produced energy and consumption of more than 40 percent of the material resources used in the society. These average estimates might differ slightly among European countries. The global governmental intention, except the US government, is to reduce the CO_2 emissions by an average

of 5 percent over the next 5 years. Some experts claim that the reduction must be 50 percent over 50 years in order to avoid large-scale climate changes.

- The usage of energy during the building's service state, called operational energy and it is one of the most important sustainability issues for the construction sector.

Energy primarily affects the environment due to the production and distribution of electricity and water for heating and cooling. The thermal performance and overall energy efficiency have an effect on the economic and environmental performance of the building, and thereby its competitiveness.

5.3 Sustainable Building Division

Four main areas are suggested for sustainable building life-cycle. Therefore, buildings that satisfy most of these four areas and their sub-sections are named as sustainable buildings. The four main areas are as follows:

1. Sustainable Design:

- Material efficiency
- Energy efficiency
- Recycle-ability
- Flexibility

2. Sustainable Construction:

- Building physics
- Waste
- Prefabrication

3. Sustainable Utilization:

- Durability
- Maintenance
- Energy
- Flexibility

4. Sustainable End of life:

- Demount-ability
- Recycle-ability
- Reusability

Reinforced concrete and steel are two popular global structural materials in building construction industry. By referring to the history of the last century there is clear indication that they are usable in different climatically, cultural and geographical regions. Now they will be considered separately by following the scopes of sustainable building. Through these observations the characteristics of how sustainable building materials and their individual impacts on the sustainable development is expected to become clear. First of all the interaction and integration of sustainability and construction will be discussed.

Then a summary on the impact of construction, sustainable design and at the end a specific review on steel and reinforced concrete structures by considering all aspects relating to sustainable structures will be discussed.

5.4 Sustainability and Construction

Permanent development is derived from the three main elements of sustainability that has already been discussed. The life-cycle of building is described in three phases; production, utilization and dismantling of the structure. Recycling process, energy consumption and material usage has unavoidable positive and/or negative effects on our planet. In fact dealing with building structure and construction development involves environmental and economical issues. Accordingly, the social matter is up to the engineers, architects and politicians.

For each building construction, there are large amounts of input materials both from virgin sources and recycled material. Initially, raw materials affect the environment through their refining processes and transportation until they become building components. Accordingly, virgin natural resources are limited and recycling option is one of the best solutions to enhance environmental performance in many cases. Joakim Widman, in an SBI publication commented that, huge amounts of waste resulted by the construction sector is more than1100 kg per capita annually in EU25; consequently the demands to improved recycling are increasing rapidly [25].

5.5 Sustainable Design

Excellent design is absolutely essential to achieve sustainable construction. United Nations Environment Program (UNEP) in Finance Initiative International Environment House indicated that the rapid depreciation and the accelerated functional obsolescence, even in new buildings, are consequences of inadequate design or frankly a poor design [26]. The greatest effect on the comprehensive sustainability is based on decisions made at the initial design stage that followed by the tight impact on the construction project and building life-cycle. “No matter how the architecture of a structure is, it is possible to transform it into an earthquake resistant one. The important concern is the technology, which is used and reached [16]”.

Furthermore to increase the public values of building it is recommended to go through a better design. Superiority of safety, security, sustainability, health and beauty is considered to achieve sustainable design. In addition, the affects of structural design on architectural design, is also important. It determines the facade and functionality of public streets, squares, parks, plazas and natural areas which are important [26].

5.6 Impact of Construction

Directly or indirectly almost everybody gets involved in major factors of sustainable development within their life. Now they can face them again but with more sophistication. Here are three fundamental elements of sustainability and accordingly the consequences of lack or weaknesses from each.

5.6.1 Economy

Recent statistics carried out within the countries of enlarged Europe was concerned with building construction investment and disclosed that €910 billion invested into this activity in 2003. In addition, by taking into account the ten new European Union countries, the amount increases up to €1000 billion. Construction accounts for about 10 percent of European GDP and the construction industry is Europe’s largest industrial employer. It provides 28 percent of industrial employment which in turn represents 7.2 percent of total employment [27].

As a result about 7 percent of the Europeans are employed in this sector. Indeed the social well-being of the majority of these people related to construction either directly or indirectly.

5.6.2 Health and Safety

Any continuous activity to reduce risks, hazards and unsafe developments should be implemented in human spaces occupied, especially in buildings. Safety with regard to hazards can constitute a significant liability for property owners and developers.

5.6.2.1 Sick Building Syndrome

Modern building techniques have been influenced by the idea that anything is possible and just because something new is discovered, does not make a better idea. One example is the modern materials used in buildings which were developed through advances in the petrochemical industry at quite a considerable cost in terms of energy and environmental damage (e.g. paint with additives, asbestos, wood preservatives, etc). Over time it has become apparent that many of these materials are unpredictable and even toxic [17].

SBI publication by Joakim Widman states that “The Sick Building Syndrome (SBS) is a modern disease caused by misplaced water in organic building components”. Characteristic of steel which minimizes the risk of SBS, direct airborne emissions and structural deterioration are resulted from neither hygroscopic nor organic steel properties. The offsite prefabrication construction method allows the steel building materials to keep dry even during assembly [25].

Almost 90 percent of our lives are spent in buildings; therefore, our well being and quality of occupancy are tightly integrated. For example, poor quality living space is responsible for health problems and this has been recognized by the World Health Organization (W.H.O.) for some 15 years in what it terms as the “sick building syndrome” and the WHO estimates that worldwide, 30 percent of offices, hotels, institutions and industrial premises have the syndrome (e.g. method used in ventilating a building, whether air-condition or natural ventilation, quality of fresh air, etc.) [28].

5.6.3 Environment

The construction and operation of buildings utilize 40 percent of the total produced energy, more than 40 percent of material resources, 16 percent of total water withdrawals and at the end generate more than 40 percent of all CO_2 (carbon dioxide) emission. The 40 percent of raw material consumed by building construction in the global economy per year is approximately-3 billion tons. Correspondingly construction activity impacts heavily on the landscape, toxic runoff into watercourses, cause of air pollution, loss of forests and agricultural land as well [29].

An investigation by The European Commission [30] pointed out in the EU-15 that construction and demolition waste amount increases up to around 180 million tons in a year. Only about 28 percent across the EU-15 is re-used or recycled and 72 percent (some 130 million tons a year) remaining in the landfill area. It means that, if the central

Paris (within the Boulevard Périphérique) were to be used, the level of waste would rise by roughly 1.3m every year. "Five Member States (Germany, the UK, France, Italy and Spain) accounted for around 80 percent of the total, broadly consistent with the share of the overall construction market accounted for by these countries" (Table 5.1).

Table 5.1: Construction and demolition waste and recycling

Member state	Core construction and demolition waste	% reused or recycled	% incinerated or land filled
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherlands	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	<5	>95
Denmark	3	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
Ireland	1	<5	>95
Luxemburg	0	N/A	N/A
EU-15	180	28	72

5.7 Sustainable Building Measures

The investigation regarding sustainable development in building profession leads to four particular phases and their specific subsection.

- The initial phase is called the **sustainable design** to express the limitation of our natural resources, energy consumption, material selection and environmental impacts.
- Next phase is **sustainable construction** for increased efficiency concerning time, cost, material and resources through the material properties.
- **Sustainable utilization** is the third phase with designing buildings for long life and a minimum of operational burdens and environmental impacts.
- The fourth phase is **sustainable end of life**. Principally this involves minimizing pollution and waste and ensuring that materials are recovered, reused and recycled.

Consequently maintenance of high and stable levels of economic growth and employment, social progress which recognizes the needs of everyone, effective protection of the environment and careful use of resources are most effective with regard to certain issues in facing with sustainable building measurement.

5.7.1 Sustainable Design

In terms of building design sustainable design is aimed to express the limitation of our natural resources, energy consumption and our obligation to future generations as well as indoor environmental quality, material selection and site planning.

5.7.2 Sustainable Construction

The second phase of a successful sustainable structure is indicated as sustainable construction issues. In other words, all possibilities that could help to reach increased efficiency in building construction work concerning time, cost, human resources, material and resources through used material properties and accuracy.

5.7.3 Sustainable Use

Building structure also deals with duration of use and safety as well. Using steel-based systems maximize the life of buildings. Although frequent reconstruction is an economical disaster in some cases in relation to building structure material but in the case of steel-based structural material it has financial value, material resource investment and in addition protects the environment.

5.7.4 Sustainable End-of-Life

As the building life comes to an end, refurbishing and building a new one might be a better option operationally and functionally. Once it is decided to demolish then it is important to carry this out with less environmental impacts, pollution and waste. Moreover, it is strongly recommended to ensure that materials are recovered, reused and recycled.

5.8 Structural Materials

5.8.1 Structural Steel

Humanity's need for housing is great and growing. About 1.1 billion people are living in inadequate housing conditions in urban areas alone. Some 21 million new housing units are required each year to accommodate present growth in developing countries. Steel is an ideal material to help meet this growing need, whether it is for basic housing or high-rise apartments [28].

5.8.2 Steel Construction

The main framing of a building using steel is called steel construction. Steel material, like other kind of structural building materials, carries specific functionality such as fasteners, building services and substructures in construction jobs. While developing on construction practice, some suggestions stated as follows:

- Material efficiency: consequences are listed as less usage of natural resources, reduced transportation, less emission and less utilization of energy;
- Ultra- high recycle-ability: outcome is less use of natural resource, reduction of waste materials and emissions;
- Quality and durability: is an approval of sustainability;
- Lean and dry construction: principles of reduction in health hazards, less wastage, less usage of energy, reduced emissions and friendly relationship with environment;
- Off-site manufacture facilitates: by fewer itinerant workers and in addition to being safer, promotes stability in the workplace, encourages skills development and fosters good local community relations;
- Flexible spaces: which have the potential to be easily modified and adapted so that the life of the building can be extended by accommodating changes in use, layout and size;

Steel Construction Sector Sustainability Committee in UK informed decision-makers like; steelwork contractors, steel producers and component manufacturers, about what is important for sustainable steel construction [32].

- Developing measurable targets for use as Key Performance Indicators for Sustainable Steel Construction;
- Measuring awareness of sustainable development issues by clients and designers;
- Making re-use of steel components more practical;
- Providing accurate information for environmentally friendly and resource efficient design;
- Increasing the appreciation of recycle-ability;

5.8.3 Reinforced Concrete

"Concrete is a man-made inorganic and inert conglomerate produced by mixing hydraulic binder (e.g. cement), water, air, fine aggregate (sand), coarse aggregate (gravel or crushed stone) with or without admixtures, reinforcement, fibers or pigments" [33].

5.8.4 Reinforced Concrete Construction

The use of concrete can offer significant benefits in the life cycle of buildings and structures.

- Thermal Efficiency: is highly efficient in reducing the energy needed to heat and cool the buildings.
- Durability: as a result minimizes maintenance and thus reduces the whole life costs.

- Mass and damping qualities: allow good acoustic performance and minimize movement and reduces floor vibration.
- Non-combustible: slow rate of heat transfer and highly effective barrier to the spread of fire.

In 2009, the Concrete Industry Sustainable Construction Forum of UK (CISCF) [34] reported that, there are a wide range of sustainability issues to consider throughout concrete’s life cycle:

- The production and transport of raw materials.
- The long term management of our operations and the restoration of our mineral extraction sites.
- The production and transport of ready-mixed concrete and pre cast concrete products.
- The process of constructing concrete buildings and other structures.
- The operational performance of concrete buildings and structures during usage.
- The reuse, recycling and disposal of concrete collected from the buildings and structures at the end of their life.

Most important parameters and key words related to an efficient comparison of two RC and steel structures, as a sustainable structure is reviewed.

In chapter 6, the critical comparison between them will be discussed. In addition, as a result of this comparison and the aforementioned evidences a more sustainable structure will be introduced.

CHAPTER 6

COMPARISON OF THE SUSTAINABILITY OF USING REINFORCED CONCRETE AND STEEL FRAME FOR A BUILDING STRUCTURE

6.1 Methodology

Up to now the argument in this thesis was based on conventional definition and application of sustainable building available in the literature. However, it is the aim of this work to identify how to minimize the damages caused by existing environmental impacts, economical matters and social hazards. The majority of building construction in Northern Cyprus is made of reinforced concrete frames. Although this is a popular structural material used in the building industry it has some unavoidable factors which are not in line with the existing fundamentals of the sustainability.

The critical matters regarding this have been discussed in chapter four. The highlighted problems are caused by building construction activities and are deeply involved with four sustainable building divisions as detailed in chapter five. Through the comparison between reinforced concrete and steel structure materials, structurally and architecturally, the LEED measuring system and the definition of sustainable building modified to a more sustainable building. A more sustainable building is achieved by maximum fulfillment of the sustainability characteristics identified as; Economic, Environmental, Social.

Although the four characteristic of the building sustainability must take into account the details of the comparison between RC and steel framed building structural material, but basic appraisal and verification of each character is beyond the scope of this thesis.

Therefore, the comparison of the sustainable building characteristics are done without going too much in detail, but at the same time all characteristics are verified in a similar manner as that of the appraisal relating to the experimental practice of the case study.

First of all a questionnaire was prepared on sustainable housing in Northern Cyprus, distributed randomly among the public and the results of it are presented and discussed in this chapter. This was followed by the modeling of a structure using architectural plans prepared on AutoCAD. The structure is modeled using ETABS software and it is used to design the building for materials, reinforced concrete and steel frame. The investigation intended to show that the use of reinforced concrete material for building frame lacks important parameters expected from sustainable housing.

Both structural materials will be measured individually according to the four sustainable building fundamentals stated in chapter five. The contribution of sustainable building measurements, computer application outputs and statistical data from the questionnaire are confirmed more sustainable building achievement. In detail, it is attempted to find out the identical and optimum level of each material in meeting the requirements of the four sustainable building areas and their subsections. For both structure types an equal and sufficient construction quality is assumed.

Consequently the more sustainable building emerged by the material which achieved the higher level from the sustainable building evaluation process.

6.2 Questionnaire on Sustainable Housing in North Cyprus

In order to investigate the sustainable housing in Northern Cyprus a questionnaire (Appendix A) was prepared with 24 conceptual questions for 100 sample size. The questionnaire was randomly distributed which eventually turned out to be five different professions such as; government staff, mechanic, restaurant owner, manager, university instructor and professor. The data analyzed with Statistical Package for Social Sciences (SPSS).

The purpose is to find out the level of knowledge of the society related to sustainable building; such as:

1. A good building definition
2. Level of adequacy of the Municipality Regulations
3. Characteristics of Sustainable building
4. The building structure designed to resist Earthquake forces
5. Advantages of recycling, reusing and repairing of materials
6. Environmental impacts that causes low efficient structural materials (e.g. CO emission)
7. Characteristics of steel structure
8. Economic sustainable building

6.2.1 Expectation of Society from a Good Building

Since the understanding of society about the characteristics of a good building which is almost the fundamentals of sustainable buildings, is reasonably adequate then any further expansion through variation of sustainability is applicable. The expectation of the society from a good building is covered under eight general effective characteristics;

4. Safe in case of natural hazard
5. Easy to repair after earthquake (if necessary)
6. Dismountable by the end of its life cycle and the structural material is 100 percent, reusable for the construction of a new building.
7. Accessible to structural elements (if needed)
8. Economic issues (for example: less occupancy of land with more internal space)
9. Less negative effects on environment
10. Fast construction
11. Flexible structure

The data analyzed with SPSS shows that a considerable percentage of society has a clear vision relating to the description of a good building (Table 6.1& Figure 6.1).

Table 6.1: Sample size and percentage of a good building description

		Sample size	Percent
A	Yes	76	100
	No	0	0
B	Yes	62	94
	no	4	6
C	yes	54	82
	no	12	18
D	yes	48	77
	no	14	23
E	yes	50	86
	no	8	14
F	yes	62	97
	no	2	3
G	yes	36	60
	no	24	40
H	yes	54	90
	no	6	10

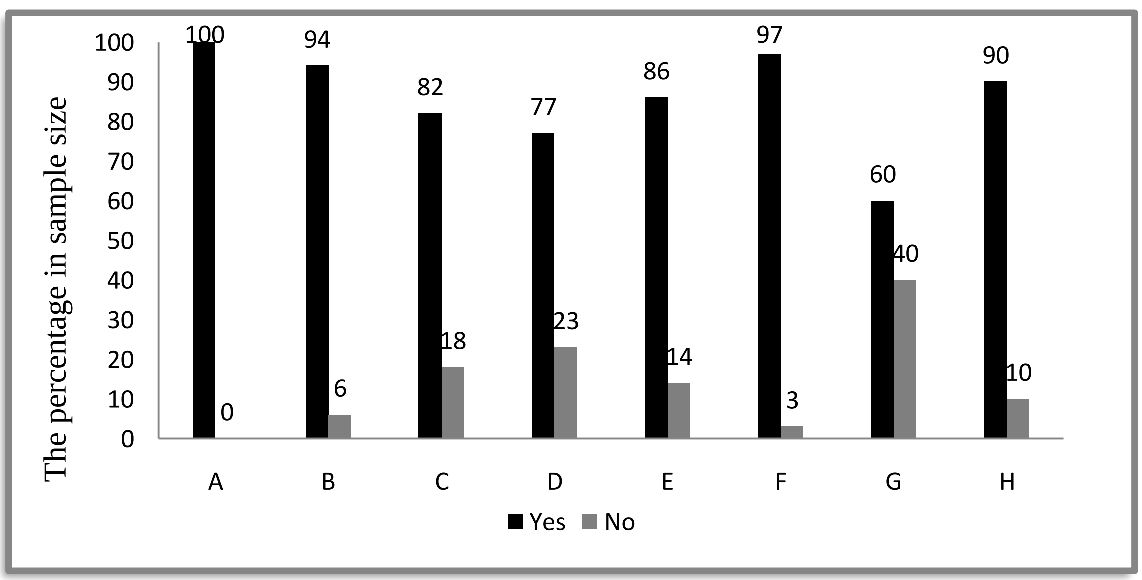

Figure 6.1: Bar chart of a good building description according to the vision of the society.

6.2.2 Level of Adequacy of the Municipality Regulations

Although the general perception of society on characteristics of a good building is quite clear, but in terms of better recognition of people's interests and their level of satisfaction from a good residential building with the current municipality regulations is investigated.

As a result (Table 6.2) the current regulations of the municipality are not sufficient for the sustainable building nature and the people's interests.

Although the regulations are not adequate the good intentions of the people through the achievement of sustainable building, will make the necessary group pressure towards changes relating to this matter.

The following questions are discussed more in detail on sustainable building subsections.

Table 6.2: Adequacy of construction regulations of municipalities in North Cyprus

	Sample size	**Percent**
yes	68	90
no	8	10

6.2.3 Characteristics of Sustainable Building

The fundamentals of sustainability in chapter two and characteristics of sustainable building structure in chapter three are discussed. As a summary, the balanced mixture of the fundamentals of Economic, Environmental and Society is the initial factor through the Sustainable Development (SD) achievement. In case of sustainable building structure the interactions and influences of each of them with the structure individually is discussed.

Consequently the building structure to achieve the characteristics of sustainability in its lifecycle is identically satisfied; appropriate economic value, minimum environmental impacts and meeting the maximum expectations of the society.

By referring to the previously explained approaches, the three fundamentals of sustainability are questioned in terms of identifying and recognizing the sustainable building among others.

Accordingly the following question was asked; do you think that the following are the quality that differentiates sustainable buildings from the others?

1. Economic
2. Safety
3. Environment

The results in Table 6.3 and Figure 6.2 are convincing that society have initial knowledge about three fundamentals of sustainability; Economic, Environment and Society Safety as part of sustainable building characteristics. Therefore, it was taken further in detail to find out more about their perception in this issue.

Table 6.3: Identifying the sustainable buildings among the others.

		Sample size	**Percent**
A	Yes	36	86
	No	6	14
B	Yes	52	87
	No	8	13
C	Yes	48	96
	No	2	4

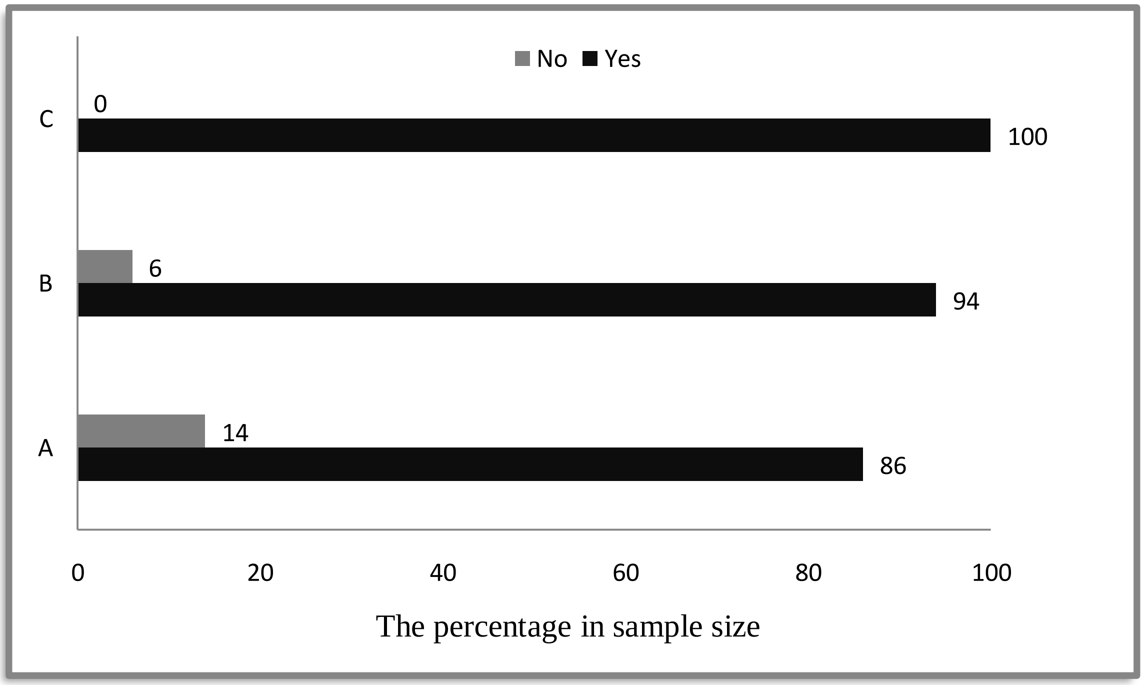

Figure6.2: The knowledge of society about the characteristics of sustainable building

6.2.4 The Building Structure Likely to be Exposed to Earthquake Forces

When the safety of a building structure is considered the possible loadings on the structures should also be thought about. Among the ones that are most critical to affect the stability of the building structure could be the wind and earthquake loads (Chapter 3). If a building is subject to earthquake loads then inevitably there could be a varying degree of damage. . The types of damage on the structure, its reparability, the availability or selection of the most efficient repair methods, possibilities of complete or partial reuse of the structure or recyclability of the materials used in the structure are among the most important factors to consider during the life cycle of any building structure.

The 50 thousand RC buildings are heavily damaged in 5 cities of Turkey in 17th of August 1999 by an Earthquake. “It is a known fact that human loss was mainly caused by the collapse of heavy buildings which were either not designed according to the Turkish seismic design code or not constructed properly for the required structural performance"[35].

The people who took part in the questionnaire expressed that the damages on the building structures as a result of an Earthquake are; complete or partial collapse of the structure and also the failure of structural elements like; beams and columns rather than damages to other structural or non-structural members (Figure 6.3).

The building structures in Northern Cyprus and in the region: for example, in Turkey, are mainly RC framed structures. The review of the properties of RC structures according to sustainable building structure measurements are given in chapter five. Although the RC structural material has reasonable level of capability in all four sustainable building divisions and their subsections, the matter of unbalanced interaction among the SD fundamentals; Economic, Environment, Society still is there. This means that, the RC structural material is only sufficient in terms of economic issue in comparison to the steel framed structure in Northern Cyprus.

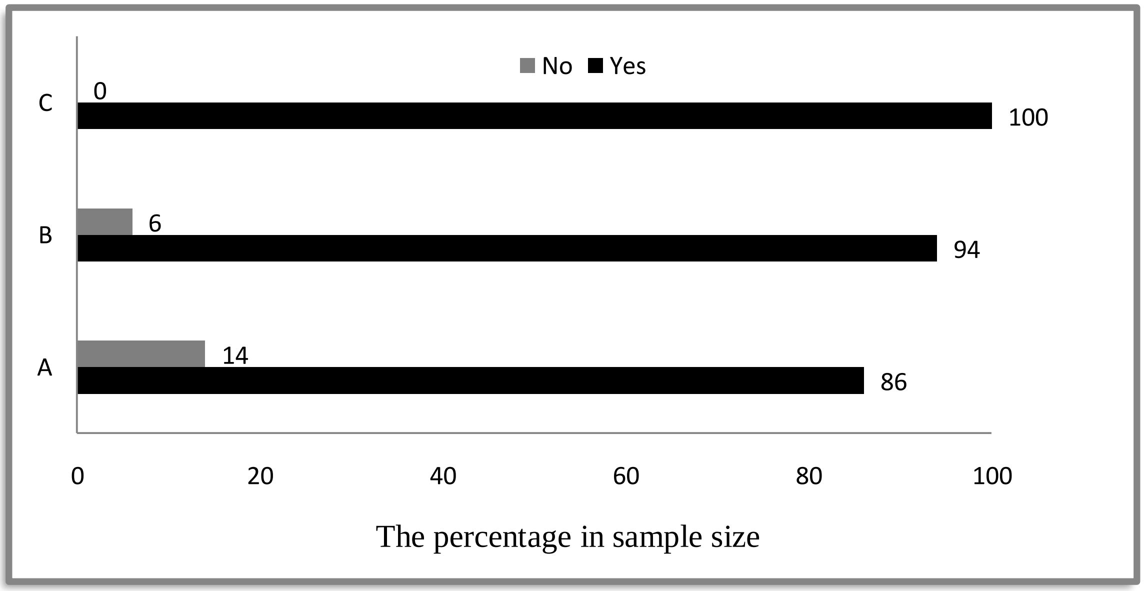

Figure 6.3: Earthquake damages

6.2.5 Advantages of Recycling and Reusing the Materials

The matter of recycling and reusing of structural materials has been mentioned briefly in chapter 3 and in more detailed in chapter 5. It was stated that by introducing more recyclable and reusable materials in the building structures it will result in less energy consumption, less natural sources and noticeable reduction in per capita cost. Although in some countries the initial coast of such recycled material is beyond the cost of original structural materials, for the sake of cleaning the landfills, less usage of the natural resources, less impact on the environment and of course more energy consumption to produce the new material it is logical to replace it with the recycled ones.

In terms of reparability, the physical properties of the material by itself and of course the interaction in facing with other used materials are concluded. It should be safe for repair, less costly and minimum level of occupancy is considered. Provided that the structure damaged by the earthquake satisfies the above mentioned repair criteria then it does not have to be demolished and the structure can be repaired and used until the end of its life.

Below given are the questions 9, 10, 11 and 12 from the questionnaire.

9. What types of damages were in that house?

    b. House completely collapsed.
    c. Partially failed.
    d. Damaged as a result of the collapse of structural elements (for example beam, column failure)

10. Were those damages repairable?
11. If not, what happened to the house?
    a. Left as it is
    b. Demolished
12. Do you think that the structure is partially or completely reusable?

Accordingly, Figure 6.4 indicated the answer to question number 10, whether the damages to the house is repairable, the Figure 6.5 shown the answers to the condition where the house is not repairable, and the Figure 6.6 indicated the reusability of the damaged structure.

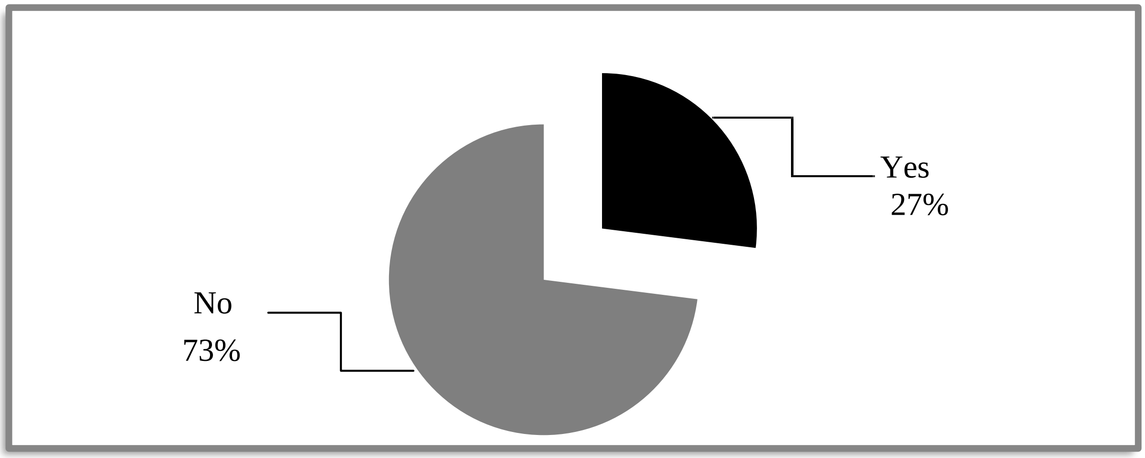

Figure 6.4: Answer to the question number 10: Are the damages to the house repairable?

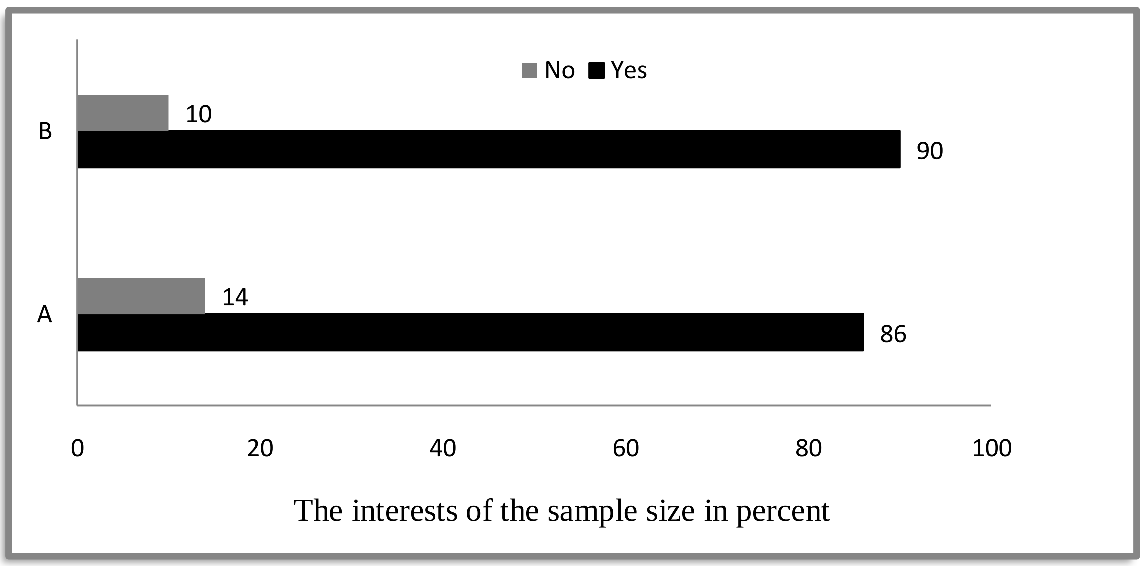

Figure 6.5: Answer to the question number 11: If the house is not repairable the, what happened to the house? a) Left as it is, b) Demolished

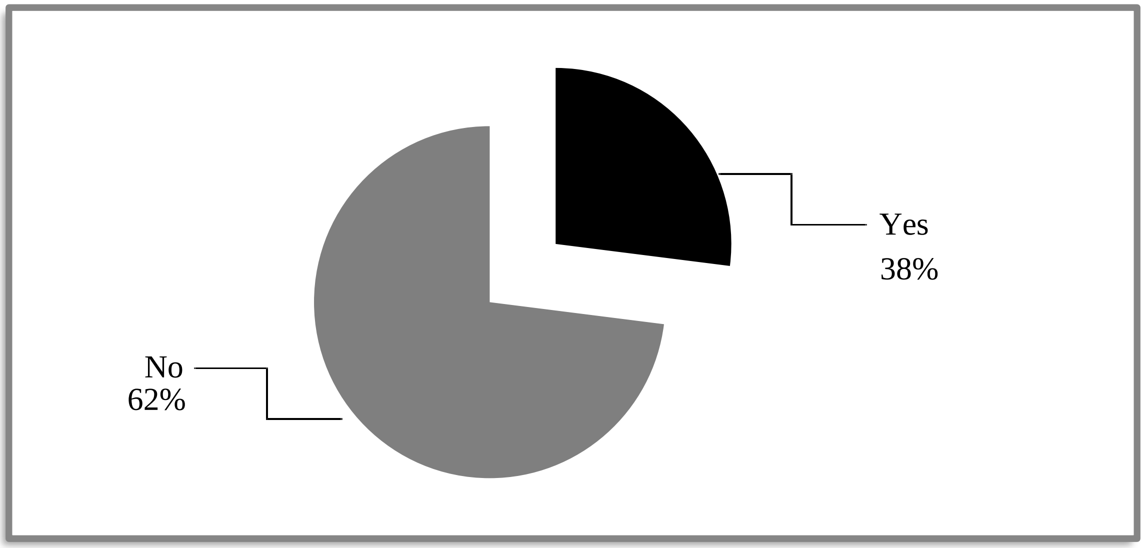

Figure6.6: Answer to the question number 12: Do you think that the structure is partially or completely reusable?

In terms of recyclability the advantages can be listed as follows:

a. Considerable reduction of the negative effects on our environment.

b. Noticeable reduction in per capita cost.

c. Reduction in the use of earth natural sources.

d. Reduction in the dangerous CO_2 gases (air pollution control).

e. Minimizing the use of energy sources.

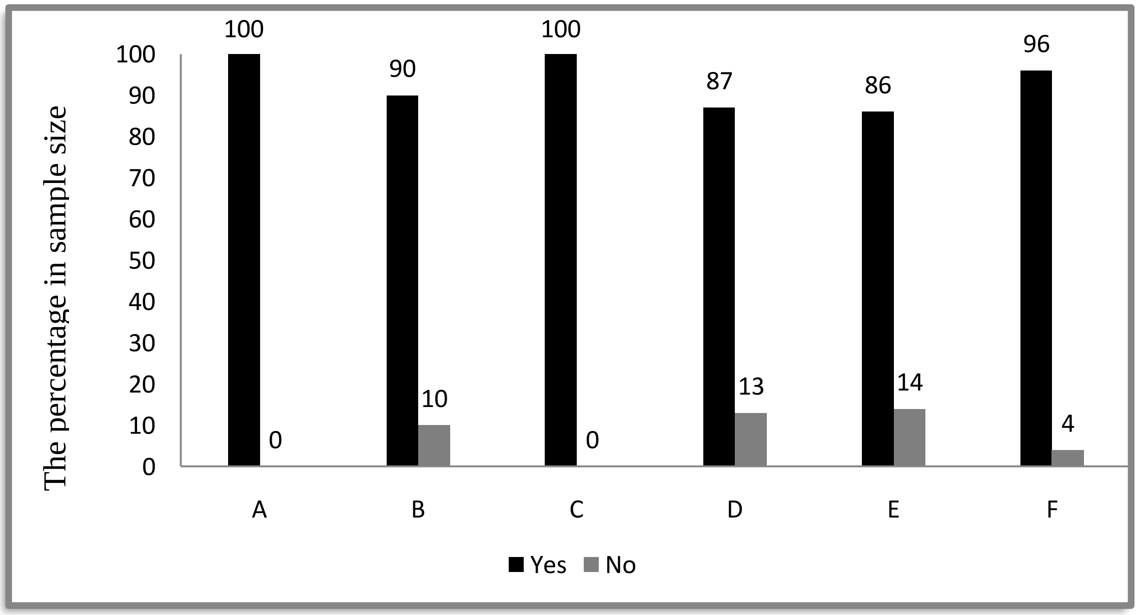

Figure 6.7: The response to the question about the benefits of recycling

6.2.6 The Environmental Impacts Due to Low or Non-Recyclable Structure Materials

In chapter five the unavoidable impacts of construction works on the two main elements of sustainable development, economy and environment, was discussed.

The construction and operation of buildings utilize 40 percent of the total produced energy, more than 40 percent of the material resources, 16 percent of the total water withdrawals and at the end generates more than 40 percent of all the CO_2 (carbon dioxide) emissions. The 40 percent of raw material consumed by building construction in global economy per year is approximately 3 billion tons [36]. Correspondingly, the construction activity impacts heavily on the landscape, toxic runoff into watercourses, cause of air pollution, loss of forests and agricultural land as well.

In terms of building construction, the high recyclable material is directly affects the reduction of CO_2 emissions, utilization of natural recourses and raw material and finally energy consumption of building industry. As a result the amount of solid waste and at the same time the landfill is reduced in order to preserve our environment.

Hence, in terms of the low or non-recyclable materials two factors are considered;

- Under which conditions a material is not counted as recyclable
- The impacts of non-recyclable material

The RC structural material is used for majority of the building constructions in Northern Cyprus. RC is a low recyclable material and required considerable energy to recycle, costly to recycle, will never have the same properties after recycling, too much waste and increase the amount of harmful CO_2 gas in the atmosphere (Chapters 4 and 5).

Therefore, all of the above mentioned matters are included in the questionnaire to get the views and response of the local people of this region regarding the building structure materials used in their houses and the results are given in Figures 6.8 and 6.9 as shown below.

The question number 17 and the response to this question (Figure 6.8) are as follow:

Do you think it is recyclable? If not why it is not recyclable?

a. The material is not recyclable.
b. It is costly to recycle it.
c. If recycled, it will never have the same properties.

d. It requires energy (electricity, human resource, coal).

e. Increases the amount of harmful CO_2 gas in the atmosphere.

f. Produces too much waste.

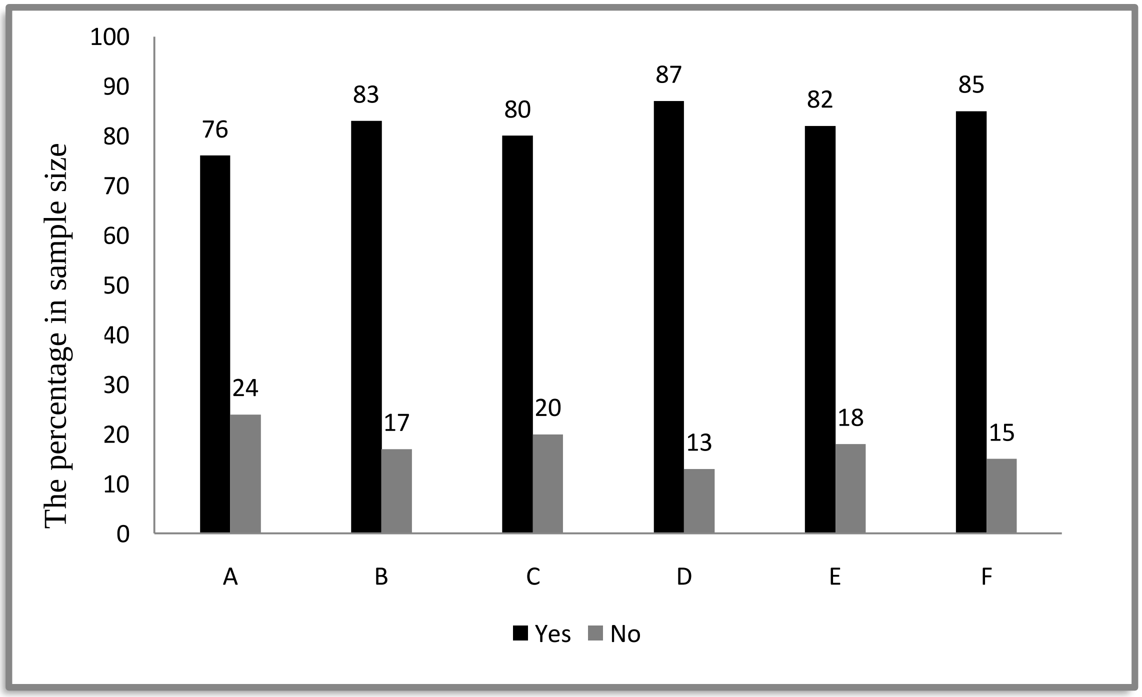

Figure 6.8: Effective characteristics of non recyclable structural materials

The question number 19 and the response to this question (Figure 6.9) are as follow:

What is the impact of non-recyclable construction materials?

a. After demolishing the building large amount of waste materials fill the land.

b. Too much energy is used (human, money, petrol and etc.) to collect them from the environment since it cannot disintegrate (Break into smaller pieces).

c. They have negative and harmful effect because of their chemical properties.

d. Use of more of our limited and valuable natural resources.

e. More money is spent to construct a new building.

f. Releasing more of harmful and dangerous CO gases to construct a new building with new material.

g. Not reusable for other construction work.

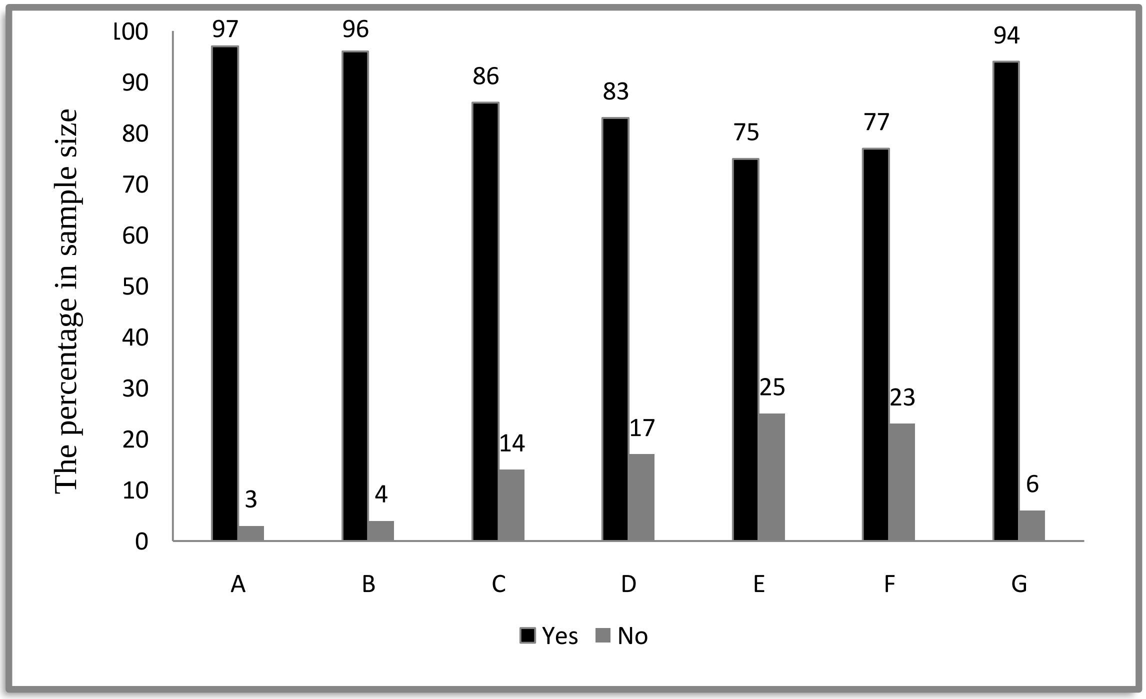

Figure 6.9: The impacts of non-recyclable construction materials

6.2.7 The Characteristics of Steel Structure

The special characteristics of steel building structures in terms of four sustainable building divisions are discussed in chapter five.

In fact the use of steel structures positively influenced the building industry. In other words;

- Faster to construct when compared to other materials (e.g. reinforced concrete);
- Easy access to damaged parts to fix or replace them if (earthquake damages);
- Above 90 percent recycling (environment friendly);
- Considerably reduction of harmful gases emission (e.g. CO_2);

- Using less interior and exterior space for construction (economical);
- Lighter weight than many of other materials (more safer during earthquake);
- More flexible in terms of architecture design by compare to other materials(e.g. concrete);
- Reusable after dismantling from another structure (economic and protect natural sources);
- Helps to strengthen the steel and concrete buildings during restoration; are briefed achievements in order to apply steel structure material in building industry.

Finally all these indicated characteristics are raised in the questionnaire to get the response of the randomly selected local people. The answers to the questionnaire indicates that majority of them are familiar with the properties of steel as a structural material (Figure 6.10).

Furthermore, they evaluated the level of sustainability of steel structure and compare the current building structure materials with steel structure material. Consequently, the people are aware of the sustainable building structures and the importance of using steel as a structural material. Therefore, they are prepared to bear extra costs relating to their building construction to ensure the safety and comfort of the intended use of the building with less environmental impacts and of course decreasing the future cost of capital.

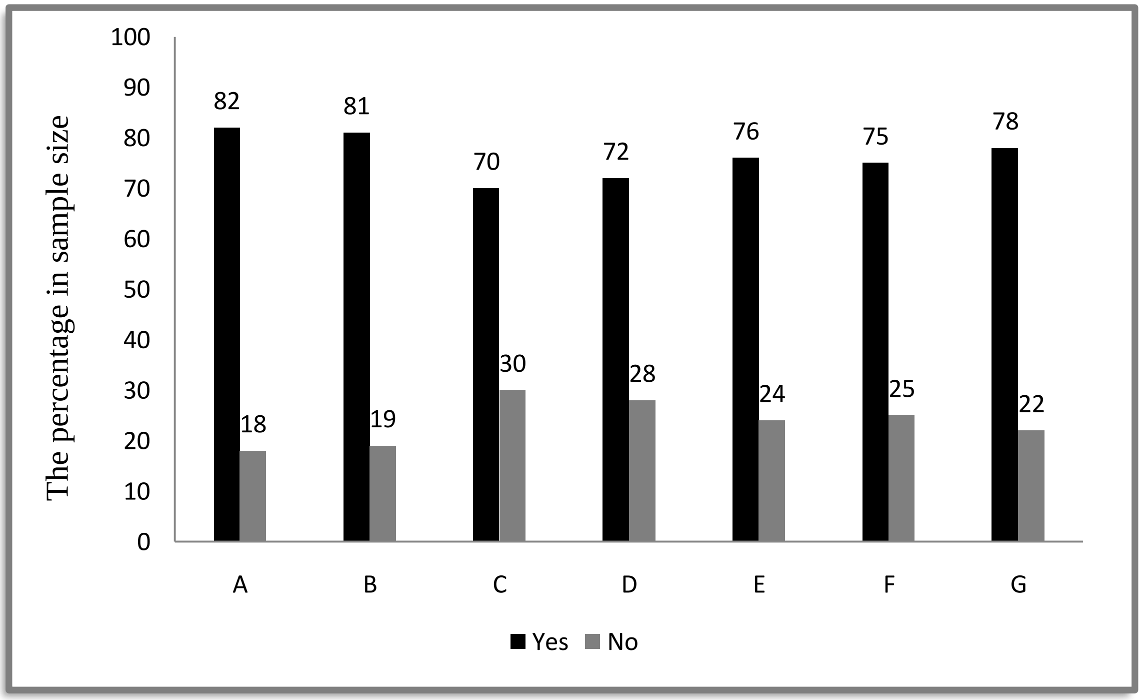

Figure 6.10: The characteristics of the steel as a structural material

6.3 Case study

The case study is an under construction residential house with 330 square meter located in the Famagusta Boaz, Northern Cyprus. The building is designed base on steel structure frame. In order of reinforced concrete structural analyzes and design initially all the architectural plans are redesigned. Finally to make more efficient practical comparison between the results of both reinforced concrete and steel frame designs is discussed.

6.4 Computer Simulation and Comparison of the Use of Reinforced Concrete and Steel Frame for a Building Structure

6.4.1 Architectural Drawing Using AutoCAD

Architectural AutoCAD plans of the building were used to do the computer modeling of the structure.

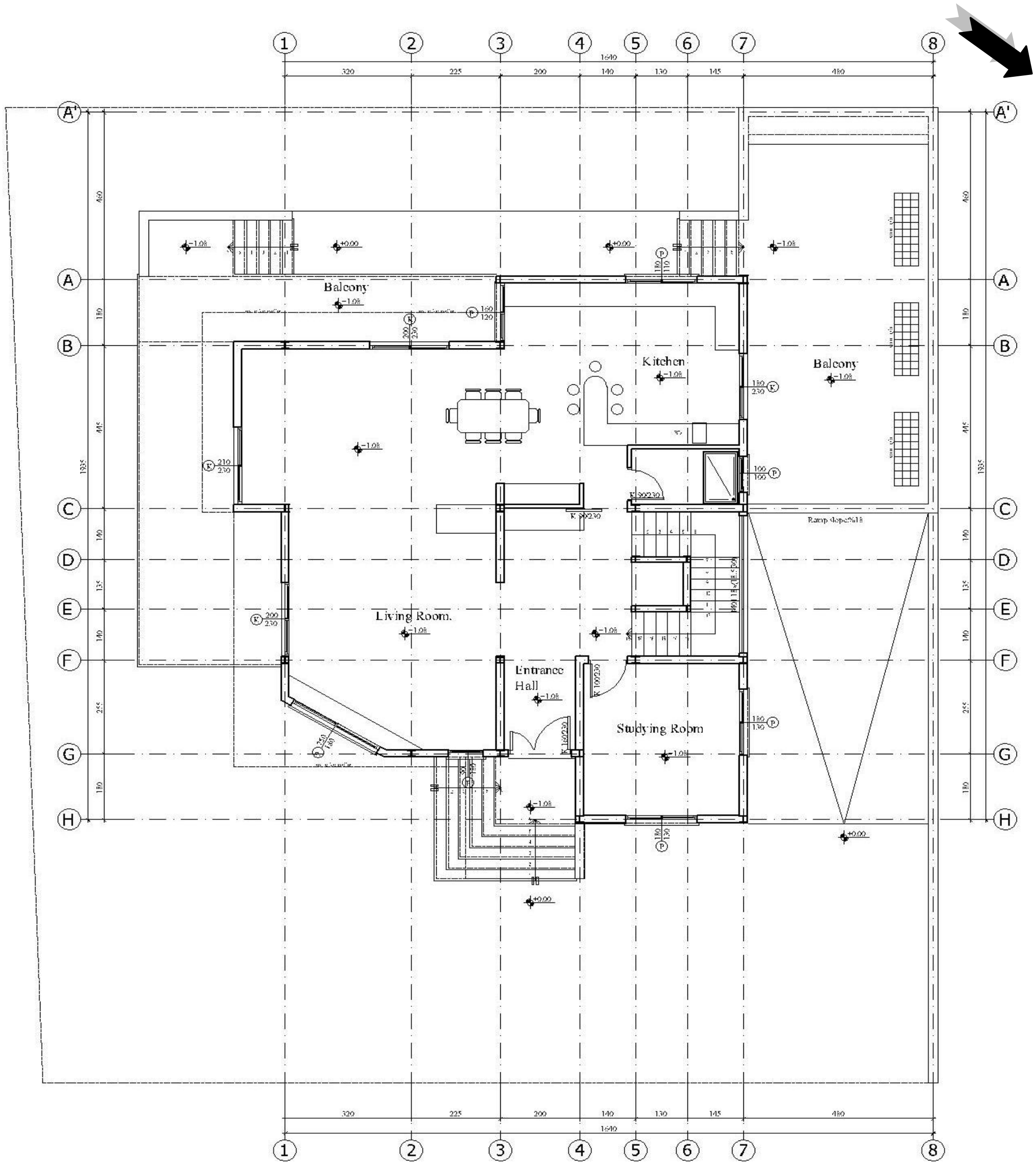

Figure 6.11: The ground floor plan of the steel framed structure

Once the model was ready then firstly it was used for the analysis and design of the steel framed structure. Then the original model was used and modified whenever necessary without changing the architectural features so that the building can be analyzed and designed as a reinforced concrete frame.

The location of the columns and gridlines were kept as per the steel framed building model (Table 6.4). In case of the beam members there were some changes in their sizes and locations of when reinforced concrete structure design was considered. In addition length of spans was also changed in some parts. Finally, the changes necessary were applied on the related parts of the architectural plans in accordance with the regulations and architectural standards.

Table 6.4: The data used both for RC and steel structure during architectural design

3RD-FLOOR	**3**	**10.74**	**2ND-FLOOR**
2ND-FLOOR	3.33	7.74	None
1ST-FLOOR	3.33	4.41	None
GR-FLOOR	2.78	1.08	None
BASE	0	-1.7	None

Both architectural drawings are edited according to the structural framing material used. As a result when the two architectural drawings are compared, design of the interior spaces and occupancy has some differences. Particularly, in the concrete framed structural drawings the total area of occupancy of the structural elements is increased nearly 5 square meters (Table 6.5). Indeed the net area of the floors, about 483 square meters for steel framed structural design is decreased to nearly 478 square meters in RC design. Although in some countries the 5 square meters difference may not be taken as a financially important matter, but the disturbances on the hierarchy of architectural design like; hindered movement within the spaces, useless additional edges on the interior surfaces, difficulties to hide the inefficient column edges and finally limited freedom in terms of design of the functional spaces is still existed.

Another difference was noticed on aesthetics and technical architectural design by using interior lines. In other words changing the architectural drawings from the steel frame to reinforced concrete frame the pure interior spaces and clear lines got disturbed.

The thickness of the slabs are covering the side edges of steel beams but the reinforced concrete (RC) beams and their specific dimensions are not covered. Obviously, by increasing the thickness of the slabs to overcome the exposure of the structural elements will increase the total weight of the structure, total project coast, use of necessary materials, and increased consumption of energy sources as a result of the use of unnecessary extra material.

Table 6.5: The total net area both for RC and steel structures from the architectural plan

STORY	Floor Area in RC Design (m^2)	Floor Area in Steel Design (m^2)
2nd Floor	43.40	44.25
1st Floor	101.57	102.85
Gr. Floor	140.60	142
Basement	191.85	193.52
Total	477.72	482.62

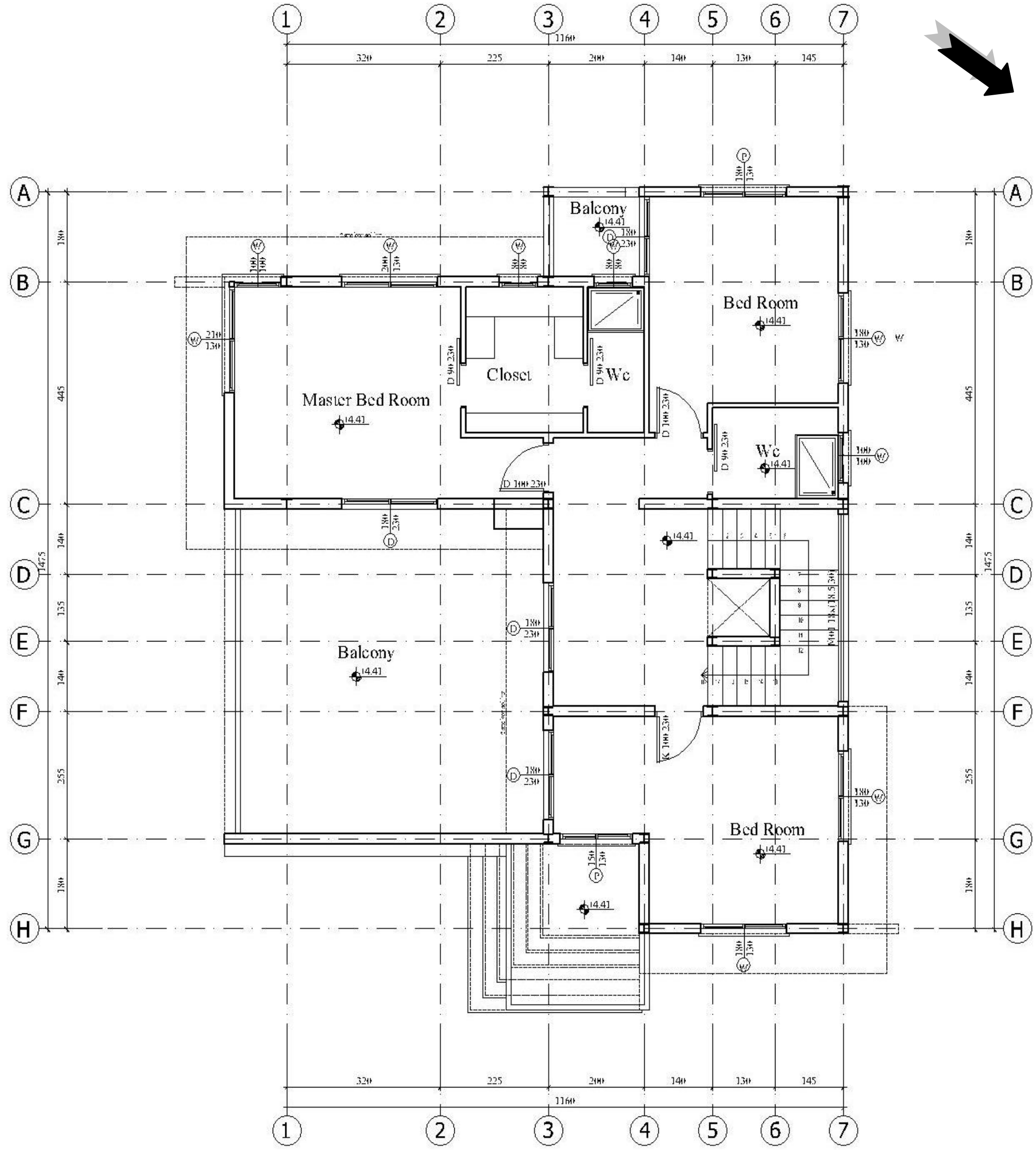

Figure 6.12: The first floor plan for the steel framed structure

Furthermore, the opportunity of using composite slabs with the galvanized deck for the steel structure would allowed the cooling, heating, piping, wires and all the necessary accesses to the technical systems to be hidden under the composite slabs (Figure 6.13).

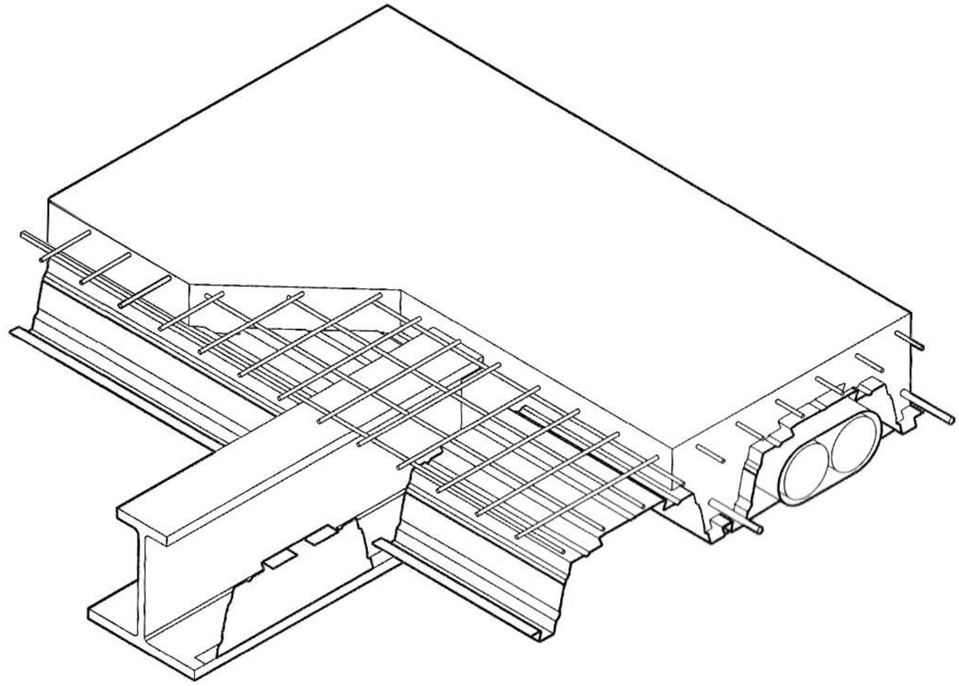

Figure 6.13: The composite slabs with the galvanized deck

Duct services can be located between the ribs in the deep decking and passed through holes in the beam web. This would allow the services to be settled within the interior space without exposing them and also in case of needing fixing or replacement there is easy access to their location without needing to break walls or ceiling. This is an extra saving in time and cost in the life time of the building.

In the case of steel structural plans the column area occupancy is less than the RC one, plus it is connecting the purity of the interior design. As a result the interior furnishing by using the existing standard sizes and models with huge varieties in the market is not difficult anymore. In addition, it allows any future changes relating to the interior design by the occupant without limiting the movement in the space provided and flexibility in accesses.

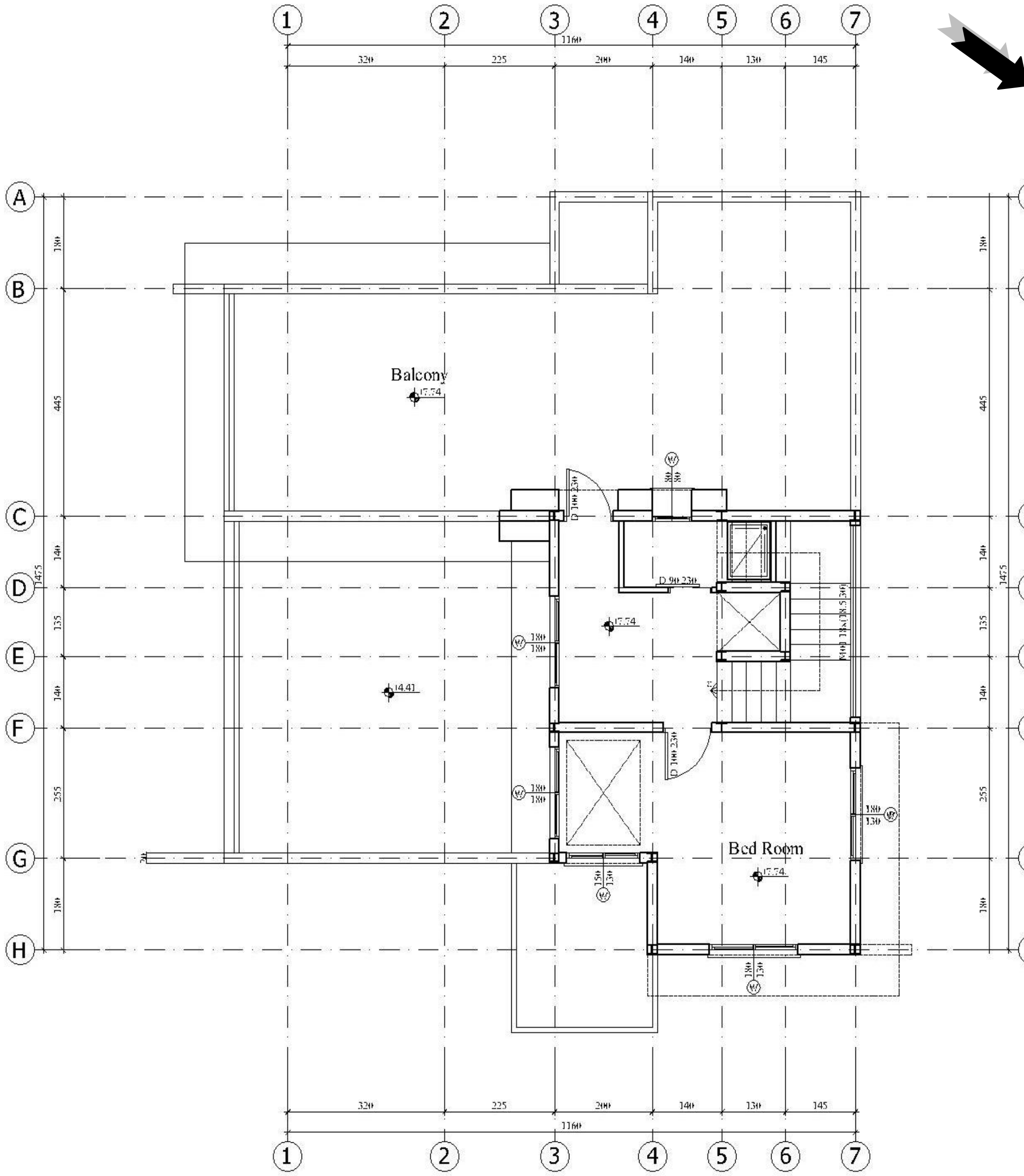

Figure 6.14: The steel structure framed flat plan

Indeed the contribution of the space flexibility, the additional architectural elements in the interior space and of course the expert design created a new and even more suitable atmosphere to increase the comfort of the residence.

It is noted that the nature of the exterior facade of RC buildings are massive with lower aesthetic appearance when compared to the huge variety of smooth movement, flexible and dynamic out scope of the steel buildings.

Finally, the use of steel framed building allows the necessary adjustments on the technical building services and facade, any future changes on interior design and even changes in the architectural plan with adequate structural safety, less cost, more suitable atmosphere for occupant, less energy consumption and time.

The next section will give the details about the modeling of the structure using steel and reinforced concrete frame and ETABS software and then comparing the two models.

6.4.2 Simulation of the Structure Using ETABS Software

The ETABS Version 8 is used for simulation, analyses and design of the structure of the case study. The influenced terms of ETABS such as; intuitive features, powerful graphical interface with unmatched modeling in analytical issues and design of building systems, helped in computer application.

Architectural plan layouts were used to make the initial modeling with gridlines for columns and beams. Then the necessary assignment to structural elements such as; material, supports system, connection properties and load cases was done. The materials were individually assigned to the structural elements for concrete and steel frame alternatives. All the supports for the foundations were defined as fixed supports .All the connections in RC design were not released. For steel frame beam ends were released in one direction.

There were five load cases assumed as; Dead Load, Live Load and three load combinations.

The P-Delta factor with five iterations was also considered to investigate the behavior of structure when subject to critical lateral movements. In addition, the most important terms such as; columns ratio, bending moment in beams are considered for both structural designs for design accuracy.

6.4.3 Reinforced Concrete Design (RC)

The structure modeling was completed by following the aforementioned steps. All the necessary definitions and assignments were applied. Seven different sections were assumed individually for beams and columns. As a result, by trial and error, the optimum point and accuracy of design were emerged. The behaviors and critical terms of the structure were observed. For instance, all column ratios, beam deflections and the structural system behavior in facing with lateral movements were observed.

6.4.4 Steel Design

The initial procedures and properties of steel model are more or less similar to the reinforced concrete one. The same column axes for both models were carefully applied to get identical comparisons. In case of steel, specific assignments like; section properties, beam and column sizes were applied and these were the obvious differences.

6.5 Outputs of Computer Application

In terms of structural weight it is different for the two buildings with two different structural framing materials. Basically extra weight will increased the cost of construction for the structure. Furthermore, technically, lighter structural material would achieve better accuracy in design. In addition, the behavior of heavier structural material is more critical when subject to different design loads, like lateral movements and earthquake force. Obviously, by the end of building life, the selection of the structural material and the degree of usage of the structural element has a direct influence on the fluctuation of waste matter. Although the amount of material utilized in terms of energy consumption, economic and use of natural resources is important, but more critical issue is the efficiency of recycling and reusing of the structural material.

Moreover, the physical property of the structural material is considered in order of the structural analyses and comparisons. In fact the physical property of the structural material is an effective matter on structural behavior when subject to lateral movement.

The inherent advantage of high ratio of the strength to weight in steel structure is manipulated for the efficiency of the building structure. Indeed, the long span capability of the steel structures created an open and column free space that is flexible enough to make different changes in utilization of the building.

The integration of services within the structural depth of the steel frames not only reduces the cost of cladding but also reduces the loss of heat through the building envelope, and facilitates the construction of additional floors for multi-storey buildings. The steel decking system allows for safe working platform and permanent formwork for the in-situ concrete.

6.5.1 Modeling finalization

The four characteristics of the sustainable building and their subsections are discussed. The structural frame weight of the RC building is approximately 450 tones when compared with the steel one, 260 tones (Tables 6.6 and 6.7). It is noted that the weight of foundation for each structure is not included in the above total weights. Therefore, the aforementioned extra weight of the RC structure can be broken down into parts as follows. The total weight of the beam and column elements in RC structure is estimated 130 tones, that is almost 5 times more than the steel one, 25 tones.

When the shear wall, slab and deck weigh is added on the weight of the RC and steel structural system the difference between the total weights of the two materials is reduced. However, the steel framed structure is still relatively lighter than the RC framed structure.

In addition, the weight of the foundation in RC structure is not considered yet and given the reasonable weight difference between the two structures the foundation weight is expected to be more for the RC structure. In fact the computer modeling of the RC framed building structure nearly 40 percent heavier than the steel framed building structure. As a result the steel framed structure is more acceptable in terms of the selection of the material.

Table 6.6: Total weight of the material listed by floor in RC structure from ETABS

STORY	Element Type	Material	Total Weight (Ton)	Unit Weight
2nd Floor	Column	CONC	9.73	0.2611
2nd Floor	Beam	CONC	10.04	0.2694
2nd Floor	Floor	CONC	17.904	0.4805
1st Floor	Column	CONC	14.66	0.1467
1st Floor	Beam	CONC	16.557	0.1656
1st Floor	Floor	CONC	48.026	0.4805
Gr. Floor	Column	CONC	16.4	0.1239
Gr. Floor	Beam	CONC	20.419	0.1542
Gr. Floor	Floor	CONC	63.611	0.4805
Basement	Column	CONC	16.697	0.0859
Basement	Beam	CONC	26.959	0.1388
Basement	Wall	CONC	93.292	0.4802
Basement	Floor	CONC	93.348	0.4805
Sum	Column	CONC	57.488	0.1239
Sum	Beam	CONC	73.975	0.1595
Sum	Wall	CONC	93.292	0.2011
Sum	Floor	CONC	222.89	0.4805
Total	**All**	**All**	**447.645**	**0.965**

Table 6.7: Total weight of material per floor for the Steel structure in ETABS

STORY	Element Type	Material	Total Weight (Ton)	Unit Weight
2nd Floor	Column	S275JR	1.716	0.0366
2nd Floor	Beam	S275JR	0.987	0.021
2nd Floor	Brace	S275JR	0.199	0.0042
2nd Floor	Floor	CONC	12.4	0.2643
2nd Floor	Metal Deck	N.A.	0.527	0.0112
1st Floor	Column	S275JR	2.606	0.0225
1st Floor	Beam	S275JR	2.658	0.023
1st Floor	Brace	S275JR	0.211	0.0018
1st Floor	Floor	CONC	30.554	0.2643
1st Floor	Metal Deck	N.A.	1.298	0.0112
Gr. Floor	Column	S275JR	2.864	0.0172
Gr. Floor	Beam	S275JR	3.814	0.023
Gr. Floor	Brace	S275JR	0.211	0.0013
Gr. Floor	Floor	CONC	43.889	0.2643
Gr. Floor	Metal Deck	N.A.	1.865	0.0112
Basement	Column	S275JR	2.885	0.0136
Basement	Beam	S275JR	3.575	0.0168
Basement	Brace	S275JR	0.151	0.0007
Basement	Wall	CONC	87.748	0.4133
Basement	Floor	CONC	56.114	0.2643
Basement	Metal Deck	N.A.	2.384	0.0112
Sum	Column	S275JR	10.07	0.0186
Sum	Beam	S275JR	11.034	0.0204
Sum	Brace	S275JR	0.773	0.0014
Sum	Wall	CONC	87.748	0.1622
Sum	Floor	CONC	142.957	0.2643
Total	**All**	**All**	**258.656**	**0.4782**

The extra weight affects the total cost of building structure. The recommended unit price of Cyprus Turkish Chamber of Civil Engineers for RC building is 930 TL/m^2 of closed area. The total cost of the RC framed structure is expected to be 444,500 TL. The cost of structural frame is approximately 40 percent of the total cost. Therefore, the cost of construction for the RC structural frame for the current case study is estimated to be 72,600 GBP (178,000 TL). Accordingly the cost of the construction of steel structure frame is computed as 54,000 GBP (133,000 TL). The cost of RC structural frame is nearly 26 percent higher than the cost of the steel structural frame. Consequently the implementation of the steel material in terms of building structure is satisfactory for the economic issues more than the RC structure frame.

The RC structure appears to be a less economical material, and unfortunately it bears the huge cost of sustainability related matters that are discussed in chapters 4 and 5 such as; repair, recycling, reusing, environmental impacts, waste management and climate change. The lower efficiency of the RC structure when subject to lateral movements is also considerable when compared to a lighter structural material like steel.

The steel structural material, as a lighter structure, has higher efficiency relating to the cost, less environmental impacts, reduced lateral movements and foundation works and safer to society, flexible in design, reusability, accessible for repair, high percentage of recyclability and minimum solid waste.

The steel structure design versus RC structure provides advantages in terms of beam element design. The steel beam web openings, away from the supports reserve the capacity over the length of a standard beam section. Consequently, the large openings usually provided without the need for strengthening by stiffeners.

The cellular beams that created by cutting and re-welding the I-section beams in steel structure system relatively reduces the axial force in the columns, but it is also capable to provide efficient long-span [37].

6.6 Sustainable Measure of RC and Steel Structures

In chapter five the four sustainable building measures; sustainable design, sustainable construction, sustainable utilization and sustainable end of life is discussed. The maintenance of high and stable levels of economic growth and employment, the social progress which recognizes the needs of everyone, the effective protection of the environment and careful use of resources are most effective certain issues that emerged by applying sustainable building measurement in all government and private projects.

Then the characteristics of two structure materials RC and steel are faced with four aforementioned measures. Although both materials are placed in sustainable category, but in order to find out the more sustainable structural material the comparison between them is investigated.

6.6.1 Sustainable Design

The first comparison term, sustainable design, is aimed to express the limitation of our natural resources and energy consumption, efficient material selection, flexible architectural plans.

The RC structural material is solid mass with lower efficiency in case of architectural design aspects, especially in terms of influences of form and space on each other. The architectural design of steel structure is more flexible and pure in creating clean line spaces. As a result the pure space design is increasingly influence the cost and functionality of the dynamic and static furniture. In addition, such a pure steady design would have influence on the concept of aesthetics.

The steel is 100 percent recyclable materials and without degradation [35]. Consequently the usage of natural sources and raw materials to produce the new steel in terms of new construction requirement is extremely reduced.

The RC material efficiency is low due to the production and construction by utilizing the natural resources and releasing harmful gases into the atmosphere. The buildings use 40 percent of raw materials globally (3 billion tons annually) [14].It is also important for our environmental values and energy efficiency scope to note that, “the energy needed to produce 1 ton of scrap based steel is about one fifth of the ore-based steel” [35].

In fact a good design and sustainable design should be synonymous with each other. Meaning that, the form, function, safety, economy, design codes and aesthetics are integrated specifically to emerge the sustainable design.

6.6.2 Sustainable Construction

All possibilities that could help to reach increased efficiency in building construction work considering time, cost, human resources, material, resources through used material properties and accuracy as well would also help us towards achieving sustainable building construction.

The RC and steel materials are evaluated with the building physics, waste and prefabrication factors are characteristics in sustainable construction that. But the most effective ones in this comparison are waste and prefabrication. The highest percentage of recycle-ability and prefabrication characteristics of steel construction extremely reduces the amount of waste when compared with the RC one. The prefabricated material reduces the waste, cost, time, energy consumed, labor and transportation; this puts the in-situ material in the second choices.

The steel construction also simplifies the logistics, increases the speed of the construction process and minimizes the pollution and noise on site [25].

It is important to mention that specific property of dry and inorganic materials in steel construction material is resisted against possible moisture during delivery, completion and erection in the way of making the construction work easier and more cost effective. As a result the dry construction is created the advantage of clean and waste free working environment during the construction operation.

Furthermore the steel construction is relatively quiet operation and requires fewer deliveries to site than other forms of construction. In addition the dust free advantage is minimized the impact on communities neighboring and the construction site [37].

Finally, in terms of the sustainable construction the advantage of using dry wall construction and aforementioned advantages of steel material puts this structural material ahead of the RC structural material.

6.6.3 Sustainable Utilization

Although the RC structure's energy factor, especially in the case of Thermal Efficiency, is highly efficient and reduces the energy needed to heat and cool buildings. But in terms of the operational energy steel structure is more effective. The operational energy is the key issue of life-cycle environmental performance. The steel framework has insignificant influence on operational energy regarding the thermal efficiency of the building envelope in combination with adopted building services. The "Steel-based envelopes can provide a well-insulated and airtight solutions, possible to combine with optional energy saving efforts" [25]. As the operational costs related to energy are significant, then there is also money to be saved.

The durability of steel frame lasts much longer than the overall building. Thereby, steel framed building durability, which is resulted from the strength characteristic of steel, brings safety and long lasting functionality for the occupants. This satisfies one of the important issues in sustainability of use.

Durability of concrete structures and technical service life depends on material and construction properties [38]. The factors which restrict the technical life of concrete are:

- Frost or salt strain,
- Carbonation leading to steel corrosion from salt strain,

- Mechanical strain (i.e. abrasion) and
- Chemical strains (i.e. attack of sulphate and acid liquids).

In case of buildings maintenance, one should try to achieve long life. It is important to note that steel-based buildings need less maintenance when compared to the RC building structures. For exposed steel construction the steel members might require regular maintenance and it is recommended that the maintenance program should be for long-term protection and as a result less environmental impact. By the time of repair all the effected structural elements should be accessible.

Furthermore, repair and if needed be replacement for the damaged element is mentioned as another possibility to maintain the building with minimum loss of occupancy, time and cost.

The task of flexibility in terms of sustainable use is accommodated in changes. The steel building structure rather than RC one is to be able to make any changes regarding to occupancy use, services, electricity, IT systems and even necessary rapid replacement of structural elements for any reason.

According to different needs of occupants the useful life of steel buildings can be extended through adaptation of internal space, structural extension and upgrading of the climate envelope. Consequently, the cost of life cycle and environmental impacts efficiently decrease.

The reduction in the use of new materials creates a corresponding reduction in embodied energy. Often sustainable architects attempt to retro-fit old structures to serve new needs in order to avoid unnecessary development [15].

Steel cladding systems produce thermally efficient building envelopes (Figure 6.15). Twin skin (built-up) and composite steel systems are durable and they achieve high levels of thermal insulation and air-tightness [37].

Figure 6.15: Thermal efficient building envelopes with steel cladding system

The steel based frame, consumes about 6.3 percent of the total life-cycle energy used by a home; while the rest of the energy is consumed by heating, cooling, refrigeration and lightning. However, the steel framed house is capable to have thermal efficiency by selecting a proper insulation system and material [37].

6.6.4 Sustainable End of Life

As the building life comes to an end, refurbishing or building a new one might be a better option operationally and functionally. In order have a sustainable end of life the three serious terms; demount-ability, recycle-ability and reuse-ability are considered. Once it is decided to demolish then it is important to carry this out with less environmental impacts, pollution and waste.

High demount-ability in steel buildings and steel construction products can illustrate the potential sustainability level of this material. Prefabricated elements, frames and modules that can be easily removed and controlled are provided a possibility to make it more conceivable. In addition, a careful design would make deconstruction and end-of-life treatment it more effective.

It is a known fact that steel is almost fully recyclable with above 90%. This means that steel material can be recycled over and over again without quality loss thereby this quality is unique for a construction material. The steel recycling rates in 2007 was reported being above 97%, which is a very strong sustainability argument for steel construction. At the same time the RC construction products recycle-ability is rated about 65% [39], which is also at a considerable level when compared with structural steel.

In terms of life-cycle scope, the materials may have down-cycling property which produces lower grade materials. Actually steel is the only material with a closed material loop, which is an important advantage when compared to many down-cycled materials. “It can be % 100 recycled to the same product, function and quality as before” [37]. Besides it is easy to convert the recycled steel into another metal product, depending upon the industrial needs and market demands.

More than 435 million tons of steel are recycled each year. On the other hand, steel industry is spending a great effort to bring the emission levels well below the upper limits. Indeed a new steel framing material contains minimum 28 percent recycled steel. Consequently, it must be realized that the constructional steel is expected to become a post consumer recycled material in the future, with an added important advantage of saving landfill spaces and contributing towards the conservation of our nature [37].

In terms of reusability the flexibility of steel construction makes an exemplary condition for renovating and refurbishing buildings. The new steel structures are used to change the plan and open up the interior of the buildings, but the existing facades can be retained. Modern steel roofing and cladding systems can be used to convert the old building up to today’s high standards of performance by re-cladding or over-cladding of the existing building[37].

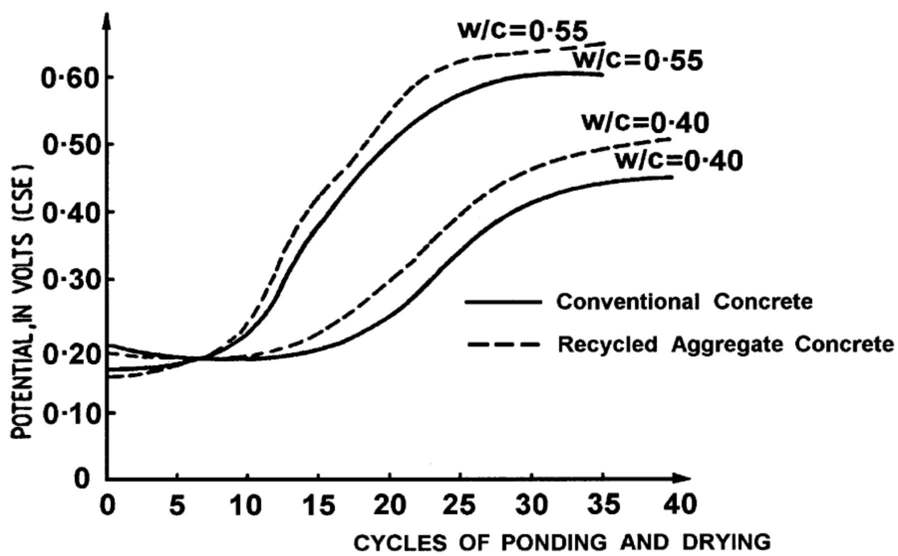

Figure 6.16: Adopted graph of half-cell potentials of steel bars embedded in specimens made from recycled and conventional aggregate concretes.

Recycle-ability of the RC construction is stated, to be efficient but different complicated procedures such as; effects of recycled aggregates on concrete properties and chloride penetration on reinforcement corrosion are still remains to be a problem. The Building Contractors Society of Japan (1978) concluded that the rate of carbonation of a recycled aggregate concrete made with concrete that had already suffered carbonation was 65% higher than the control concrete made with conventional aggregates (Figure 6.14).

The Building Contractors Society of Japan also concluded that reinforcement in recycled concrete may corrode faster than in conventional concrete. This accelerated corrosion, however, could be offset by reducing the water cement ratio of the recycled concrete. Additional studies by Rasheeduzzafar [40] also confirmed these conclusions. Therefore, RC construction subject to recycling requires more accurate control, cost, energy consumption, natural resources. This whole process is more complicated than the recycling of steel.

The possibility of reuse-ability in most of the building structure materials is very little and for some cases none, whilst for steel-based frame it can be up to 100 percent.

Moreover the reuse of steel material specially within building construction has an environmental advantage which is even greater than recycling benefits individually. Finally, comparing the properties of concrete with steel, the RC building structure is not sufficient in any reusability task.

6.7 The LEED Rating System

The LEED rating system (Chapter 3) with six major areas; Sustainable sites, Water efficiency, Energy and atmosphere, Materials and resources, Indoor environmental quality and Innovation and design process are prepared by U.S Green building council for U.S.A. It is possible to modify and applying a rating like LEED to other countries, only after doing adequate research and collecting necessary data. Therefore, a system similar to LEED can be applied to North Cyprus in future. It is important that initially the culture of the country and then the municipality regulations, economic issues, environmental capabilities and the facilities in the country should be considered. Accordingly, the experimental investigation and accurate data collection within the specific time required by LEED is needed to measure the RC and steel framed buildings.

Consequently an approximate comparison of the material and resources major of the LEED, which is one of the critical matters in the North Cyprus and of course possible to estimate with existing data in the research, is discussed. However, experimental data is needed for the rest of the five majors for their analyses and these measures are mostly related to issues, such as, surrounding environment, facilities in the country and municipality regulations rather than the structural materials. Therefore, it can fairly be assumed that in the cases of RC and steel building structure, all five measures would be identical since these measures are not directly comparing the buildings.

The comparison of the material and resources are discussed in Table 6.8 for RC and steel building materials. As a result the steel building material satisfies this measure well above the RC building material. Therefore, the huge differences in rating system places steel building material above the RC in the LEED certification level.

Table 6.8: The rating of RC and steel material with material and resources of the LEED (Adopted information from LEED for new construction& major renovation v.2.2)

		Point	RC material point	Steel material point
Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1	-	1
Credit 1.2	**Building Reuse**, Maintain 95% of Existing Walls, Floors & Roof	1	-	1
Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1	-	1
Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1	-	1
Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1	-	1
Credit 3.1	**Materials Reuse**, 5%	1	-	1
Credit 3.2	**Materials Reuse**, 10%	1	-	1
Credit 4.1	**Recycled Content**, 10% (post-consumer + 1/2 pre-consumer)	1	-	1
Credit 4.2	**Recycled Content**, 20% (post-consumer + 1/2 pre-consumer)	1	-	1
Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1	1	-
Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1		1
Credit 6	**Rapidly Renewable Materials**	1	-	1
Credit 7	**Certified Wood**	1	-	1
Total		**13**	**1**	**12**

CHAPTER 7

DISCUSSION OF RESULTS AND CONCLUSION

7.1 Discussion of Results

The contribution of four sustainable building characteristics, structural modeling, architectural plan and questionnaire on sustainable buildings in North Cyprus relating to the appraisal of RC and steel structural material is discussed.

Following the general investigation on the sustainability issues in building industry of the North Cyprus and the Mediterranean region, a case study of a building with RC and steel structural material alternatives was carried out to demonstrate which framing material provides a more sustainable building. As a result of this comparison between a RC and steel framed structure, it was revealed that the **steel framed building** is **more sustainable** and **more economical** for construction. Steel framed structure satisfies the critical issues relating to **sustainable building,** which are **sustainable design, sustainable construction, sustainable utilization and sustainable end of life,** more than the RC framed building (chapters 5 and 6).

Constructional steel presents more advantages relating to sustainable building and development than the RC one. For instance:

- economical
- reusability, recyclability, serviceability
- refurbishment, less maintenance cost
- lighter structure, faster construction, continuous construction
- easy access to the services, flexibility in design and utilization
- more energy efficiency, minimum environmental impacts

In addition, when considering the earthquake resistance, durability and ease in reusability or dismountable buildings; steel construction becomes a very strong building alternative. It gains a special importance concerning the required structural performance, strengthening of the damaged buildings and waste material management especially in the earthquake areas.

Using the LEED rating for the “Material and resources” the comparison between the RC and steel building structure indicates that despite the RC building structure material being sustainable, for the level of satisfaction and measurement of the material and recourses, the LEED rating, is considerably higher for the steel structure building.

Although the reinforced concrete is the traditional building structural material in the Northern part of Cyprus, the economic perception of the steel structure frame is considerably cheaper (**26 percent**) than the RC structure frame.

Consequently the steel building construction possible achievements in the North Cyprus could be noted as:

- **Economical sustainable housing**
- **Clean environment**
- **Minimum solid waste**

These are some of the important issues in the three fundamentals of sustainable development**, economy, environment and society.** The progress in the use of steel material in building industry of North Cyprus will progressively lead the country to reach the sustainable development.

7.2 Conclusion

As a result, it is important to note that; constructional steel must be continuously and seriously promoted, appraised and implemented to the society as an efficient alternative building material in the Northern part of Cyprus construction market in order to convince the governments, building owners, architects, civil engineers and building contractors to build in steel against the other traditional building systems.

The **steel housing is more sustainable** and of course it is **cheaper** than the current RC building in the Northern part of Cyprus. By considering the outcome of the questionnaire from the members of the society and also the stated advantages of structural steel building against the RC building, **it is more rational to use the steel material in the building industry in North Cyprus.**

Therefore, it is responsibility of all architects, civil engineers, government and private sectors of the Northern part of Cyprus to gradually change from the current inefficient building system on one hand and the huge dangerous environmental impacts on the other hand. Obviously, the transition to green building industry is achievable only by considering all the aforementioned missing elements in terms of sustainable housing in the country and the steps to take the adequate urgent decisions.

In addition, in terms of sustainable developments they should attempt to lead the people to make them more aware of the inefficient housing market and the construction products. This is the only way to safeguard the implementation of the sustainable development in different areas of construction industry of North Cyprus at present time and in the future; the clean environment, safer living for the society and of course more stable economy.

Finally, as human beings, we all are responsible to protect the Erath for the next generations.

Note that; Sustainability is preserving the future.

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APPENDIX

Questionnaire on Sustainable Housing in TRNC and SPSS Statistics Data

Questionnaire on Sustainable housing in TRNC No:

Age:

Gender:

Status:

Education:

Nationality:

1. Do you agree that the below given are brief descriptions of a good building? a) Safe in case of natural hazard b) Easy to repair after earthquake (if necessary) c) Dismountable by the end of its life cycle and the structural material is 100% reusable to construct a new building. d) Accessibility to structural elements (if needed) e) Economic issues (for example: less occupancy of land with more internal space) f) Less negative effects on environment g) Fast construction h) Flexible structure	YES	NO
2. Do you prefer to have/built a safe house with a different structural frame material than the current one?	YES	NO
3. Do you think that the building construction regulations of your municipality are satisfactory for the residents?	YES	NO
4. Do you know anything about sustainability?	YES	NO
5. Do you know any sustainable building in TRNC?	YES	NO
6. What kinds of construction material/s are used for this building? a) Reinforced concrete b) Steel c) Stone		

d) Wood		
7. Do you think that the following are the quality that differentiates sustainable buildings from the others? a. Economic b. Safety c. Environment	YES	NO
8. Have you ever seen a house that was damaged by an earthquake or have you heard from someone who has seen one?	YES	NO
9. What types of damages were in that house? a. House completely collapsed. b. Partially failed. c. Damaged as a result of the collapse of structural elements (for example beam, column failure)		
10. Were those damages repairable?	YES	NO
11. If not, what happened to the house? a. Left as it is b. Demolished		
12. Do you think that the structure is partially or completely reusable?	YES	NO
13. What do you thing are the main reason/s for the collapse of a building as a result of an earthquake? a. Construction faults b. Quality of materials used c. Stability and geotechnical problems d. Other……..		
14. What do you know about recycling of building materials?		
15. What are the benefits of recycling? a. Considerable reduction of the negative effects on our environment. b. Noticeable reduction in per capita cost. c. Reduction in use of our natural sources.		

d. Reduction in the dangerous CO_2 gases (air pollution control) e. Minimizes the use of energy sources. f. Use of waste products in other types of production.		
16. Which material is used in your building frame? a. Reinforced concrete b. Steel c. Stone d. Wood		
17. Do you think it is recyclable? If not why it is not recyclable? a. The material is not recyclable. b. It is costly to recycle it. c. If recycled, it will never have the same properties. d. It requires energy (electricity, human resource, coal). e. Increases the amount of harmful CO_2 gas in the atmosphere. f. Produces too much waste.		
18. If yes is it beneficial to do so?	YES	NO
19. What is the impact of non-recyclable construction materials? a. After demolishing the building large amount of waste materials fill the land. b. Too much energy is used (human, money, petrol and etc.) to collect them from the environment since it cannot disintegrate (Break into smaller pieces). c. They have negative and harmful effect because of their chemical properties. d. Use of more of our limited and valuable natural resources. e. More money is spent to construct a new building. f. Releasing more of harmful and dangerous CO_2 gases to construct a new building with new material. g. Not reusable for other construction work.		
20. What is your estimation of the time and cost required to clean the environment?		

a. Very Little time and high cost b. Too Much time and low cost c. Too Much time and high cost d. Very Little time and low cost e. It is not necessary to do any estimation of time and cost of cleaning environment since that will happen by itself.		
21. Do you prefer to have/build your house with more recyclable structural material, for example using around 90% recyclable material when compared to current materials?	YES	NO
22. Do you know that steel structures have different properties? For instance : a. Faster to construct when compared to other materials, e.g. reinforced concrete. b. Easy access to damaged parts to fix or replace them if necessary (earthquake damages). c. Above 90% recyclable d. Using less interior and exterior space for construction (economical) e. Lighter weight than many of other materials (more safer during earthquake) f. Reusable after dismantling from another structure (economic and helps to save the natural sources) g. Helps to strengthen the steel and concrete buildings during restoration.	YES	NO
23. Do you prefer to live in such a house?	YES	NO
24. With an extra cost, do you think it is logical to use more recycle-able and safer building materials to reduce the environmental impacts and therefore future costs of building by decreasing the cost?	YES	NO

Anket: KKTC`ndeki sürdürülebilir binalar No:

Yaş:

Cinsiyet:

Konumu:

Eğitimi:

Uyruğu:

1. Aşağıda belirtilen kısa tanımların standard iyi bir bina için olduğuna katılıyormusunuz? a) Doğal tehlike durumunda güvenli b) Deprem sonrasında kolay onarım (eğer gerekliyse) c) Kullanılabilir yaşam süresi sonunda malzemenin 100% tekrar bina inşaasında kullanılabilmesi. d) Yapısal elemanlara ulaşılabilirlilik (eğer gerekliyse) e) Ekonomik sorunlar (örneğin: daha fazla iç mekan ve daha az arazi kullanımı) f) Çevreye daha az zarar g) Hızlı inşaat h) Esnek yapı	EVET	HAYIR
2. Günümüzde kullanılandan daha farklı yaklaşımlarla güvenli bina inşaa etmeyi tercih ediyor musunuz?	EVET	HAYIR
3. Belediyenizin konut yapım alakalı kanunlarının yeterli olduğunu düşünüyor musunuz?	EVET	HAYIR
4. Sürdürülebilirlik ile ilgili herhangi bir şey biliyor musun?	EVET	HAYIR
5. KKTC`nde herhangi bir sürdürülebilir bina biliyormusunuz?	EVET	HAYIR
6. Bu tür binalarda hangi tür taşıyıcı sistem kullanılır? a. Betonarme yapılar b. Çelik c. Taş		

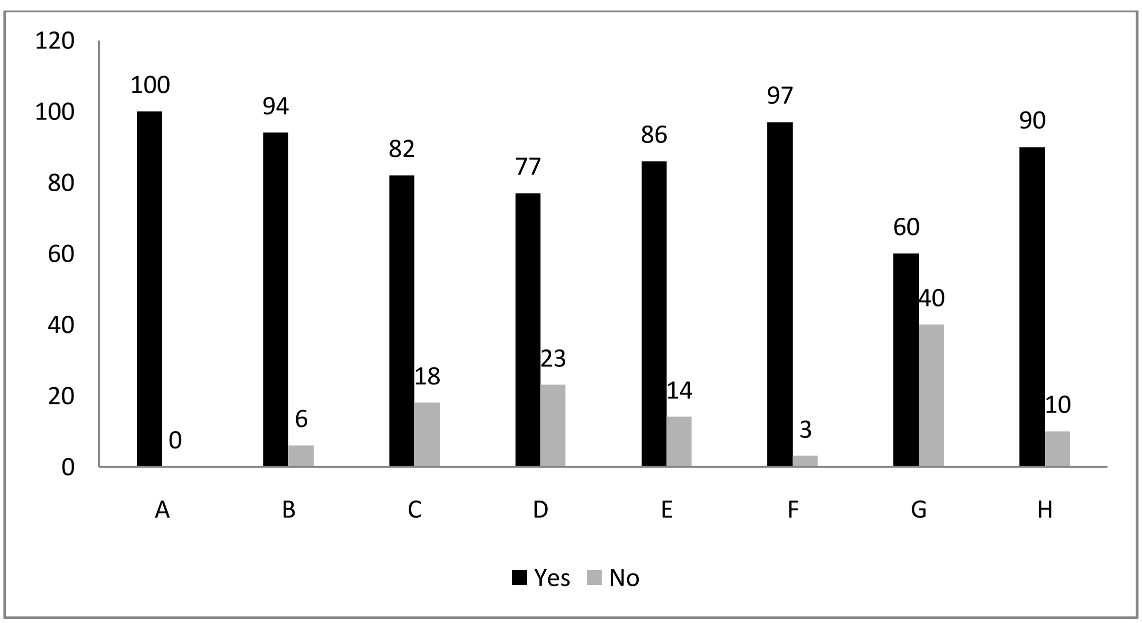
d. Ahşap		
7. Sizce aşağıdaki sürdürülebilir yapıları diğerlerinden farklı kılan nitelikler midir? a. Ekonomi b. Güvenli c. Çevre	EVET	HAYIR
8. Depremde hasara uğramış bina gördünüzmü yada tanıdığınız birileri gördü mü?	EVET	HAYIR
9. Bu binada hangi tür hasarlar vardı? a. Bina tamamen yıkıldı. b. Bölgesel yıkılma oldu. c. Bina elemanlarında kırılmalar oldu (örneğin: kiriş yada kolon göçmesi)		
10. Bu binalar tamir edilebilirmiydi?	EVET	HAYIR
11. Eğer hayırsa, bu binalara ne oldu? a. Olduğu gibi bırakıldı b. Yıkıldı		
12. Yapıların tümu yada bir kısmı yeniden kullanılabilimi?	EVET	HAYIR
13. Sizce binanın çökmesine aşağıdakilerden hangileri neden olabilir? a. Yapım hatası b. Kullanılan malzeme kalitesi c. Zemin ve geoteknik sorunlar d. Diğerleri……..		
14. Yeniden kullanılabilir yapı malzemeleri hakkında ne biliyorsunuz?		
15. Yeniden kullanılırlığın ne gibi faydaları vardır? a. Çevre üstündeki olumsuz etkilerin azaltılması. b. Kişi başına düşen maliyetin azalması. c. Doğal kaynakların kullanımının azlaması.		

d. CO_2 gaz salımının azlaması (hava kirliliğinin kontrolü) e. Enerji kaynaklarının asgari kullanımı. f. Atıkların diğer üretimlerde kullanımı.		
16. Yaşadığınız binada hangi tür taşıyıcı sistem kullanılmıştır? a. Betonarme yapılar b. Çelik c. Taş d. Ahşap		
17. Geri dönüşümlü olduğunu düşünüyormusunuz? Eğer hayırsa niçin? a. Kullanılan malzemelerin geri dönüşümlü olmaması. b. Geri dönüşümün pahalı olması. c. Geri dönüştürülürse ayni malzeme özelliklerinin olmayacağından d. Enerji ihtiyacından. (elektrik, insan kaynakları, kömür) e. CO_2 gaz miktarını atmosferde artıracağından. f. Çok fazla miktarda atık olacağından.		
18. Eğer evetse yapılması faydalı olurmu?	EVET	HAYIR
19. Geri dönüşümlü olmayan bina malzemelerinin ne gibi etkileri vardır? a. Yıkımdan sonra atık malzemelerle arazilerin dolması. b. Tam olarak doğada yok olmadıkları için toplanması çok fazla enerji kullanımı gerektirir (elektrik, insan kaynakları, petrol vs.). c. Kimyasal özellikleri nedeniyle olumsuz ve zararlı etkileri vardır. d. Sınırlı ve değerli doğal kaynakların daha fazla kullanımı. e. Yeni bina inşaası için daha fazla para harcanması. f. Yeni malzeme ile yeni bir bina inşa etmek daha fazla zararlı ve tehlikeli CO_2 gazlarının daha yüksek oranda g. Atmosfere bırakılmasıDiğer inşaat çalışmaları için yeniden kullanılabilir olmaması.		

20. Çevre temizliği için zaman ve maliyet miktarı ? a. Çok az zaman ve yüksek maliyet b. Çok fazla zaman ve az maliyet c. Çok fazla zaman ve çok maliyet Çok az zaman ve çok az maliyet d. Çevre kendi kendini temizlediğinden zaman ve maliyet tahminleri gerekli değil.		
21. Mevcut malzemelere gore daha fazla geri dönüşümlü yapı malzemesi kullanarakörneğin %90 civarında kullanarak, geri dönüşümlü ev sahibi olmayı tercih eder misiniz?	EVET	HAYIR
22. Çelik yapıların farklı özellikleri olduğunu biliyor musun? Örneğin: a. Diğer yapım malzemelerine gore, örneğin betonarme, daha hızlı inşaat zamanı, Hasarlı parçalara kolay erişim, düzeltmek yada değiştirmek gerektiğinde.(deprem hasarı) b. % 90'nın üzerinde geri dönüşümlüdür c. Inşaat için daha az iç ve dış mekan kullanımı (ekonomik) d. Diğer malzemelerden çok daha hafif (deprem sırasında daha güvenli) e. Bir yapıdan söküldükten sonar yeniden kullanılabilir (ekonomik ve doğal kaynakları korur) f. Çelik veya betonarme binaların restore etmede ve güçlendirmede yardımcı olur.	EVET	HAYIR
23. Böyle bir evde yaşamayı tercih eder misiniz?	EVET	HAYIR
24. Bu tür geri dönüşümlü binaları kullanarak ekstra bir maliyet ile daha güvenli yapı sağlamak, binanın gelecekteki maliyetlerini ve çevresel etkilerini azaltmak mantıklı mı?	EVET	HAYIR

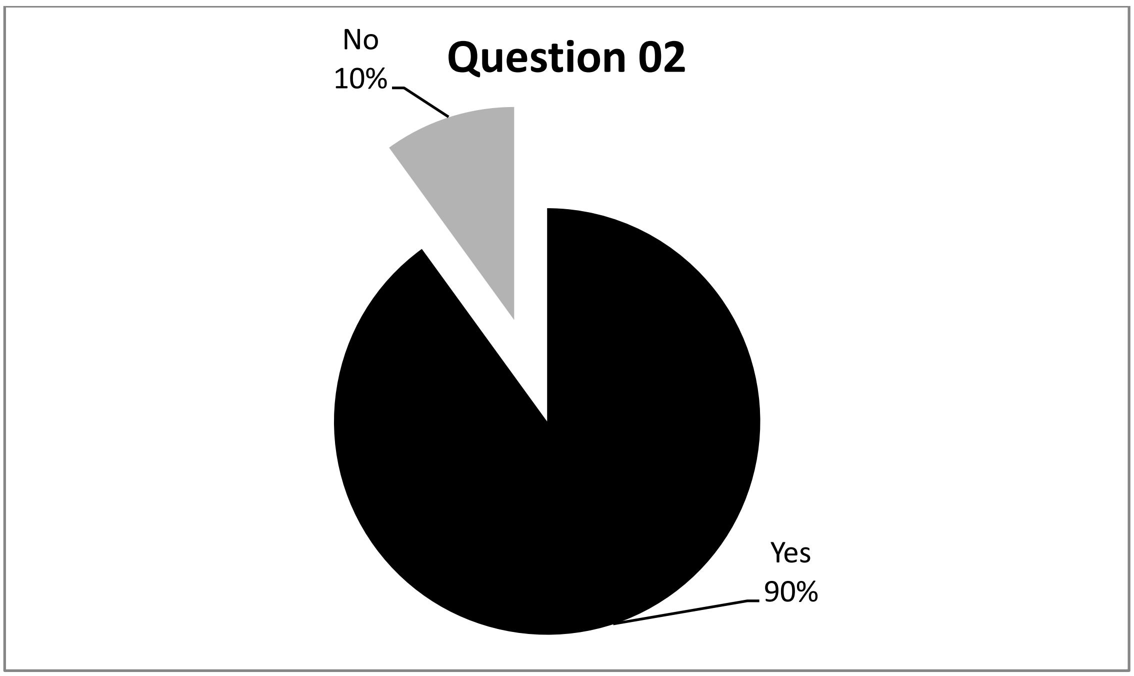
Question: 1

		Sample Size	Percent
A	yes	76	100
	no	0	0
B	yes	62	94
	no	4	6
C	yes	54	82
	no	12	18
D	yes	54	77
	no	14	23
E	yes	50	86
	no	8	14
F	yes	62	97
	no	2	3
G	yes	36	60
	no	24	40
H	yes	54	90
	no	6	10



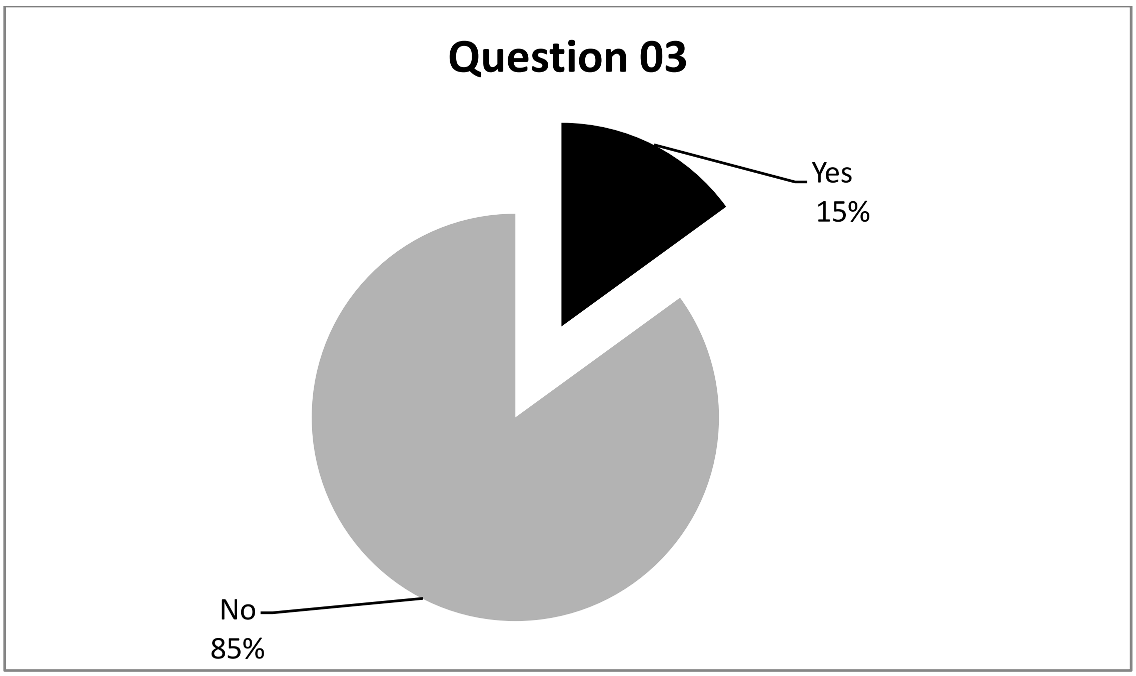
Question: 2

	Sample Size	Percent
yes	68	90
no	8	10



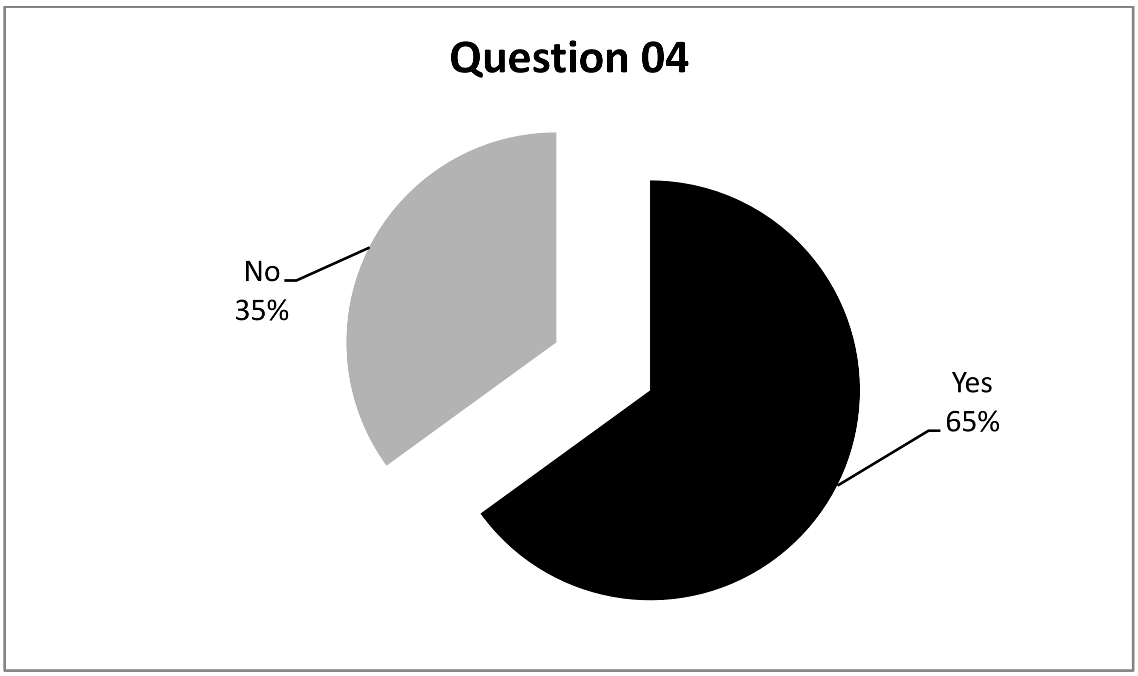
Question: 3

	Sample Size	Percent
yes	12	15
no	66	85



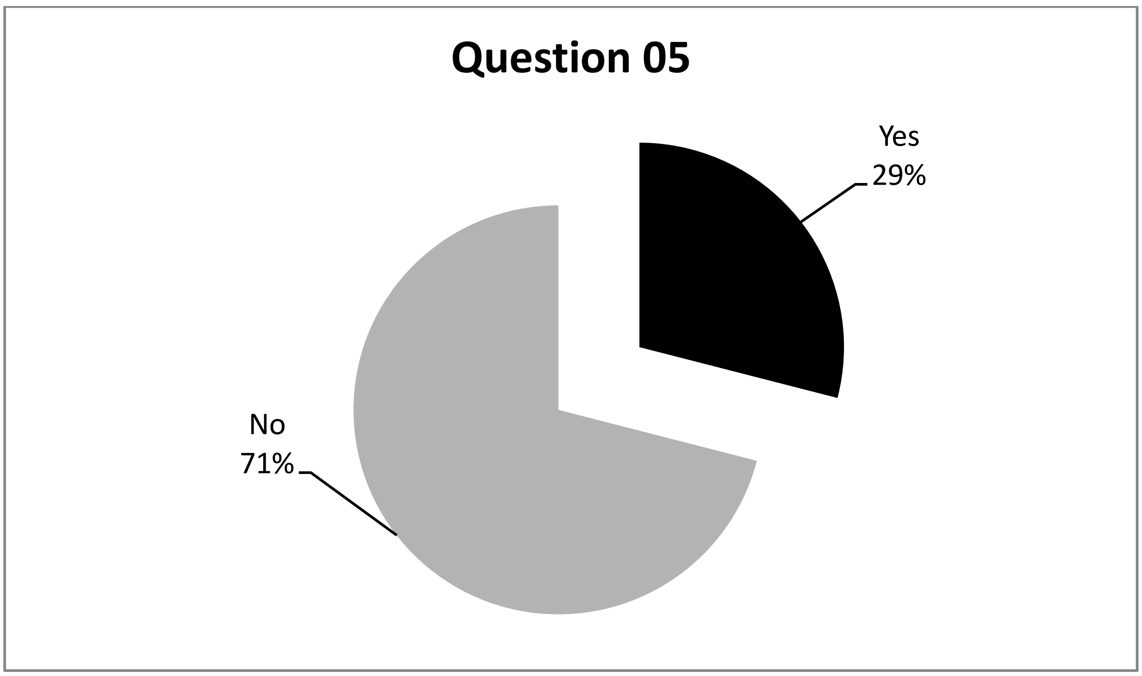
Question: 4

	Sample Size	Percent
yes	52	65
no	28	35



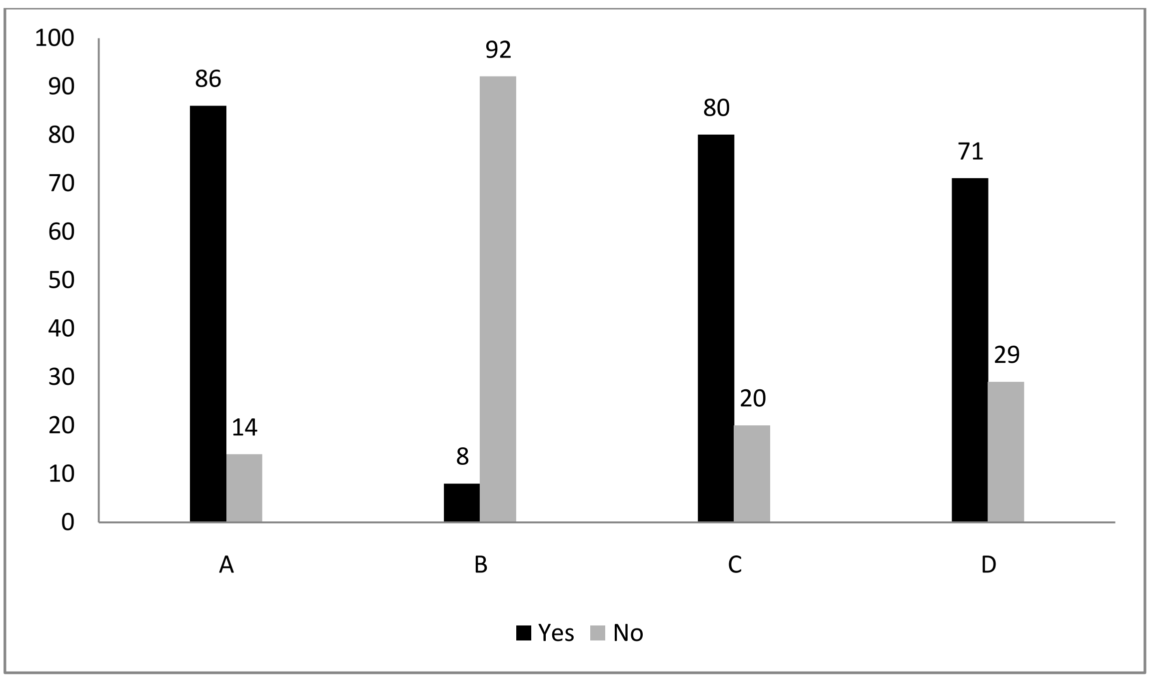
Question: 5

	Sample Size	Percent
yes	20	29
no	48	71



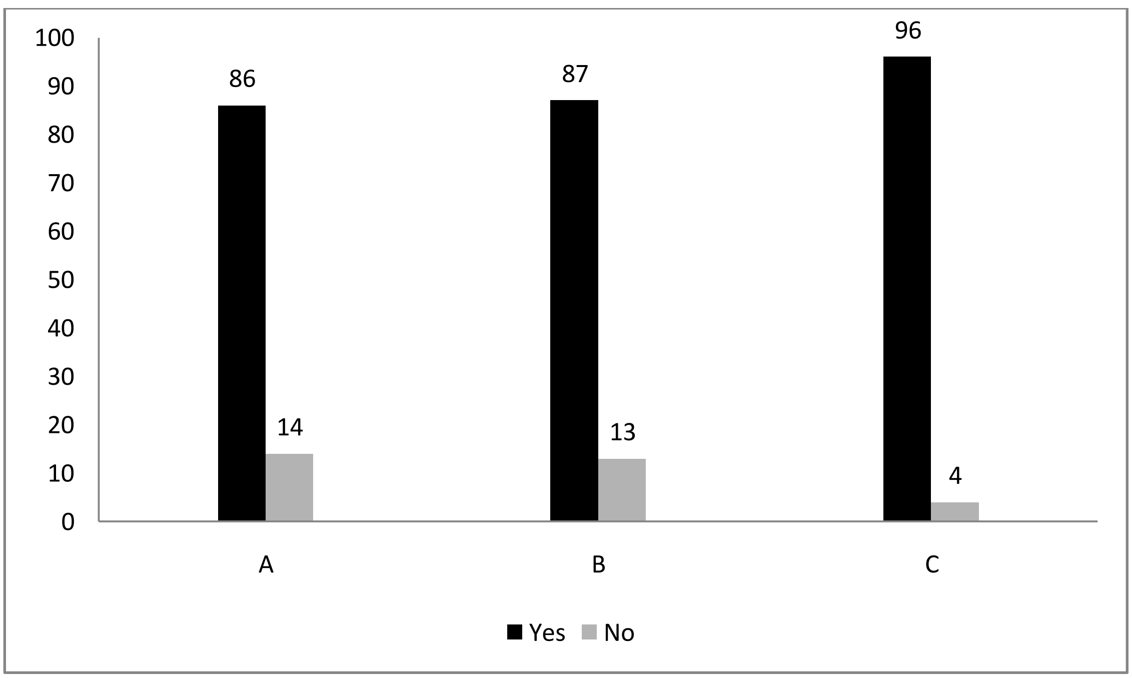
Question: 6

		Sample Size	Percent
A	yes	24	86
	no	4	14
B	yes	2	8
	no	24	92
C	yes	16	80
	no	4	20
D	yes	10	71
	no	4	29



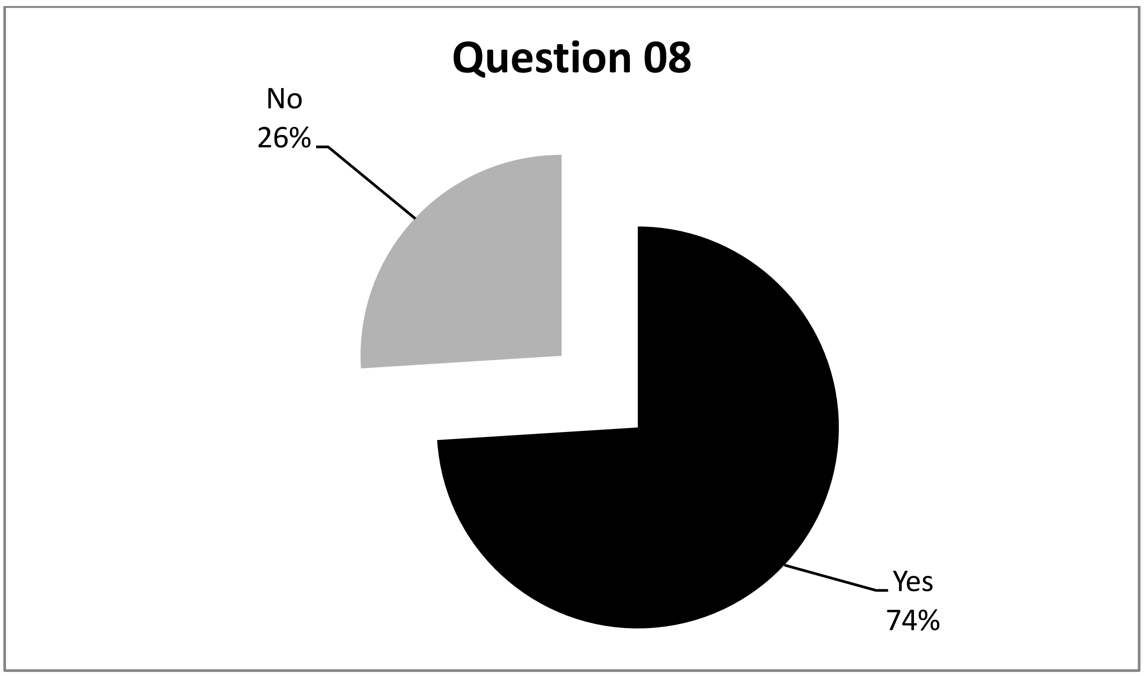
Question: 7

		Sample Size	Percent
A	yes	36	86
	no	6	14
B	yes	52	87
	no	8	13
C	yes	48	96
	no	2	4



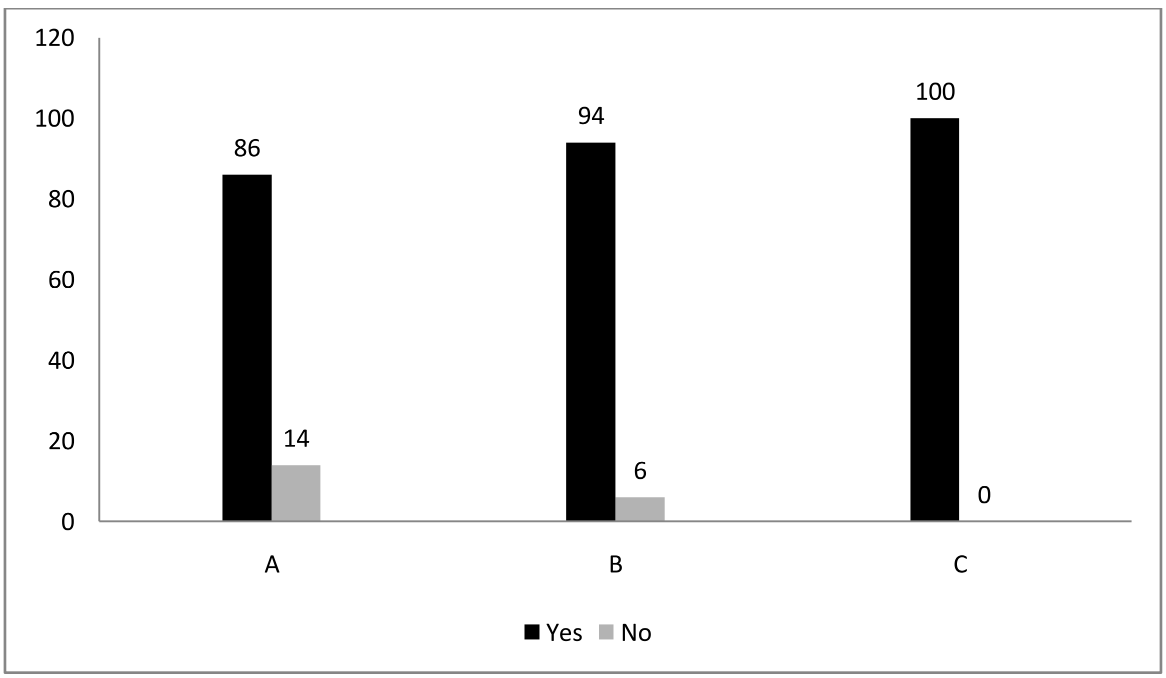
Question: 8

	Sample Size	Percent
yes	78	74
no	20	26



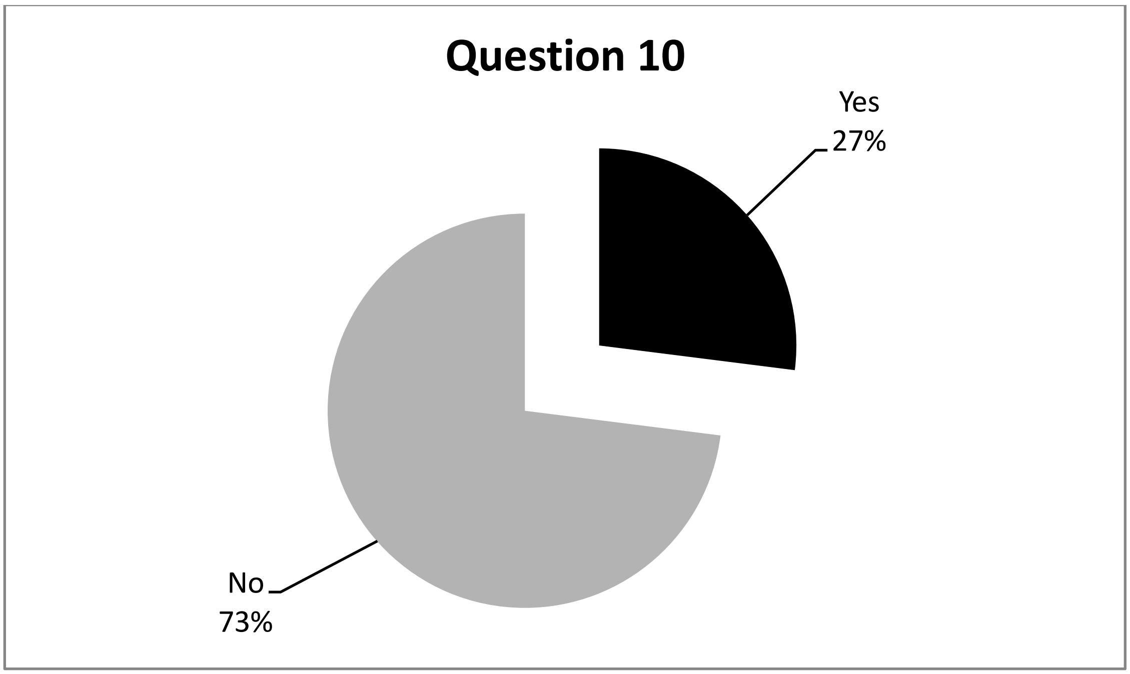
Question: 9

		Sample Size	Percent
A	yes	24	86
	no	4	14
B	yes	30	94
	no	2	6
C	yes	30	100
	no	0	0



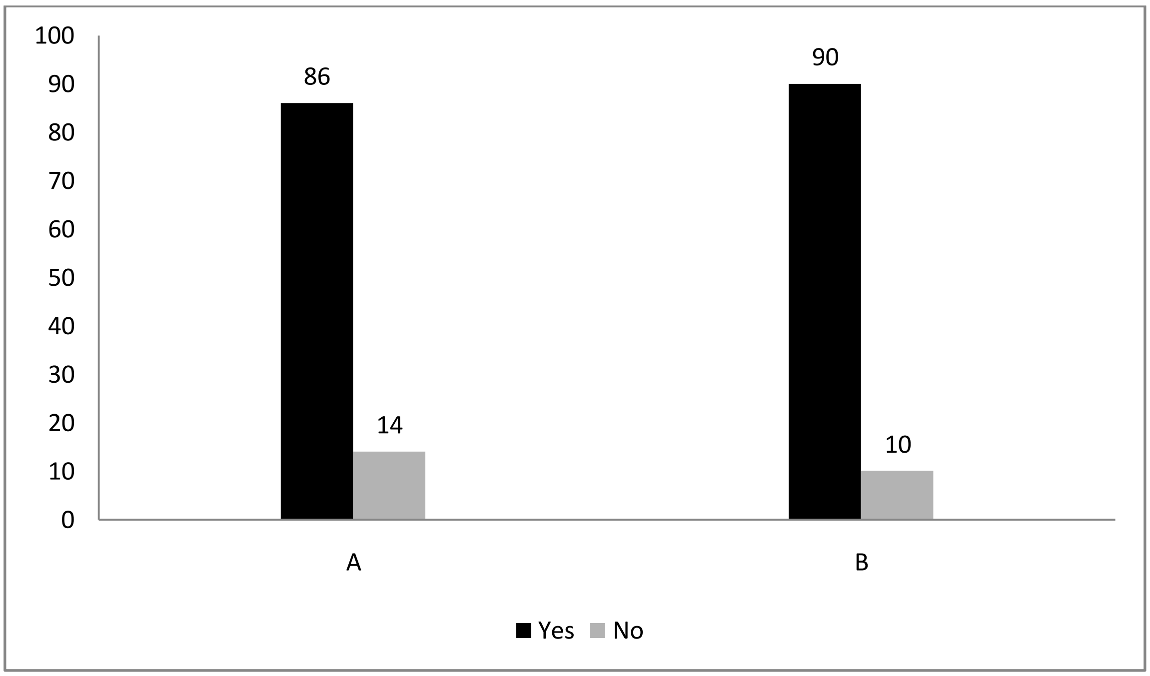
Question: 10

	Sample Size	Percent
yes	14	27
no	38	73



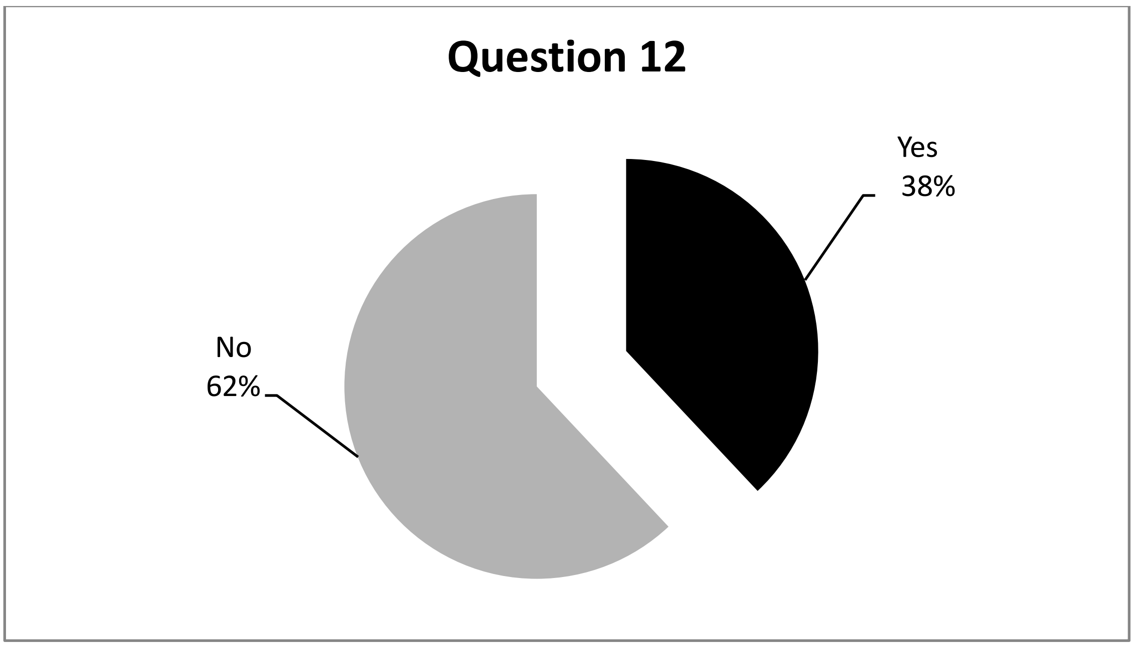
Question: 11

		Sample Size	Percent
A	yes	12	86
	no	2	14
B	yes	36	90
	no	4	10



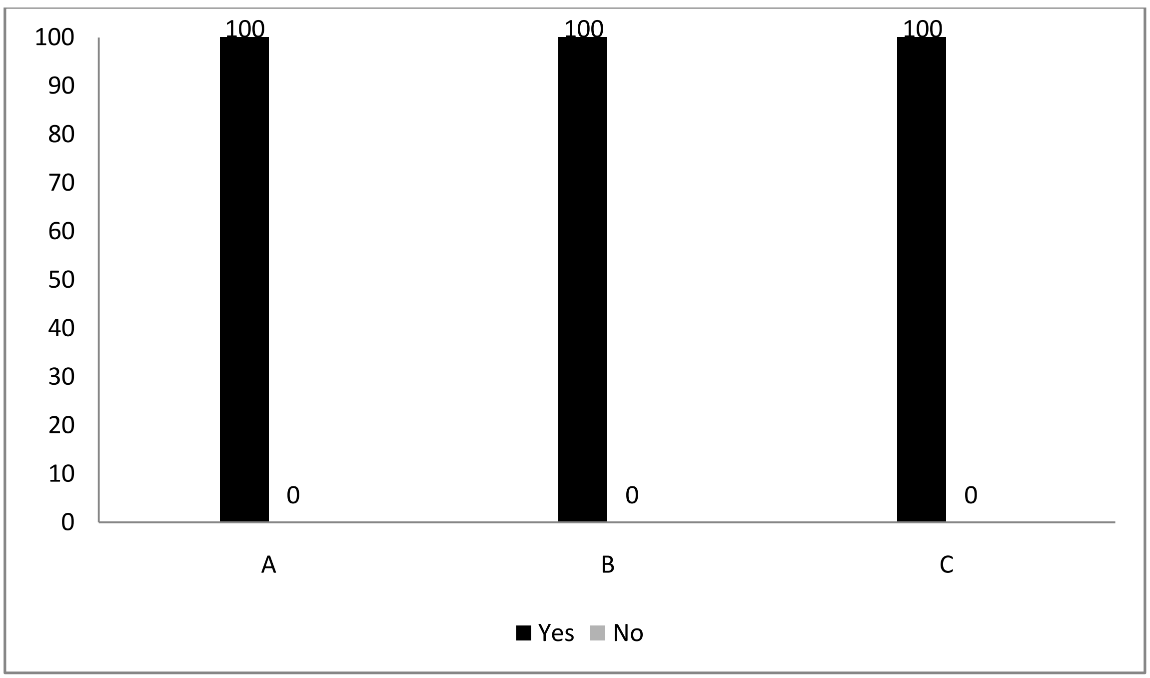
Question: 12

	Sample Size	Percent
yes	20	38
no	34	62



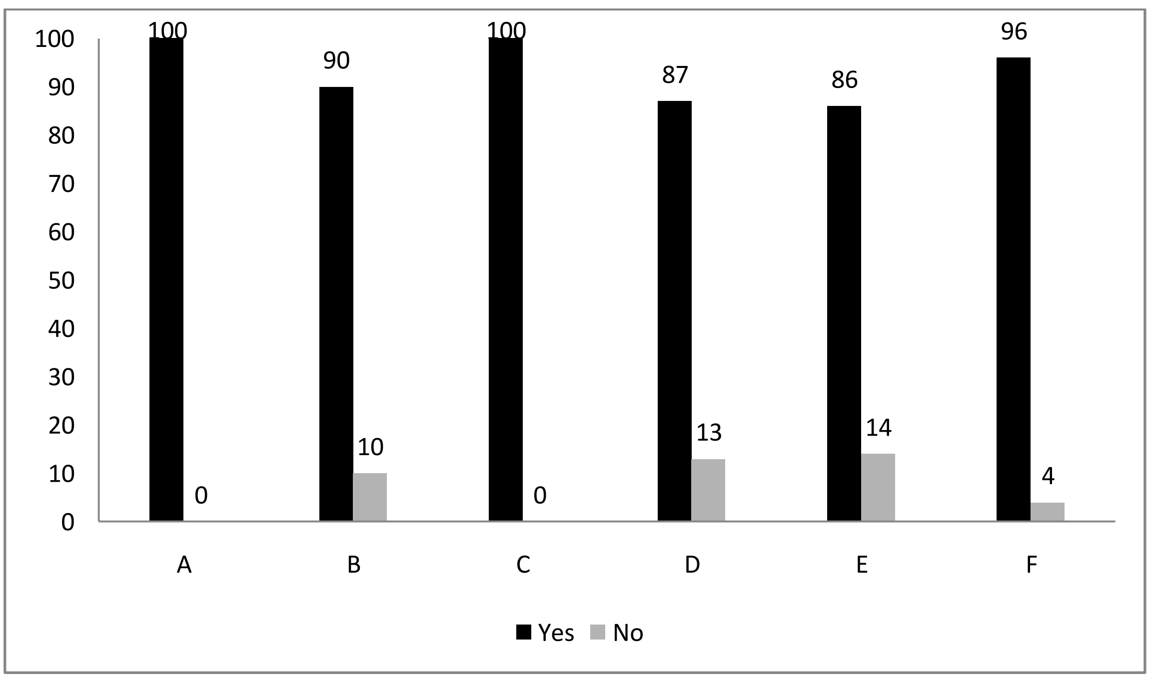
Question: 13

		Sample Size	Percent
A	yes	52	100
	no	0	0
B	yes	60	100
	no	0	0
C	yes	52	100
	no	0	0



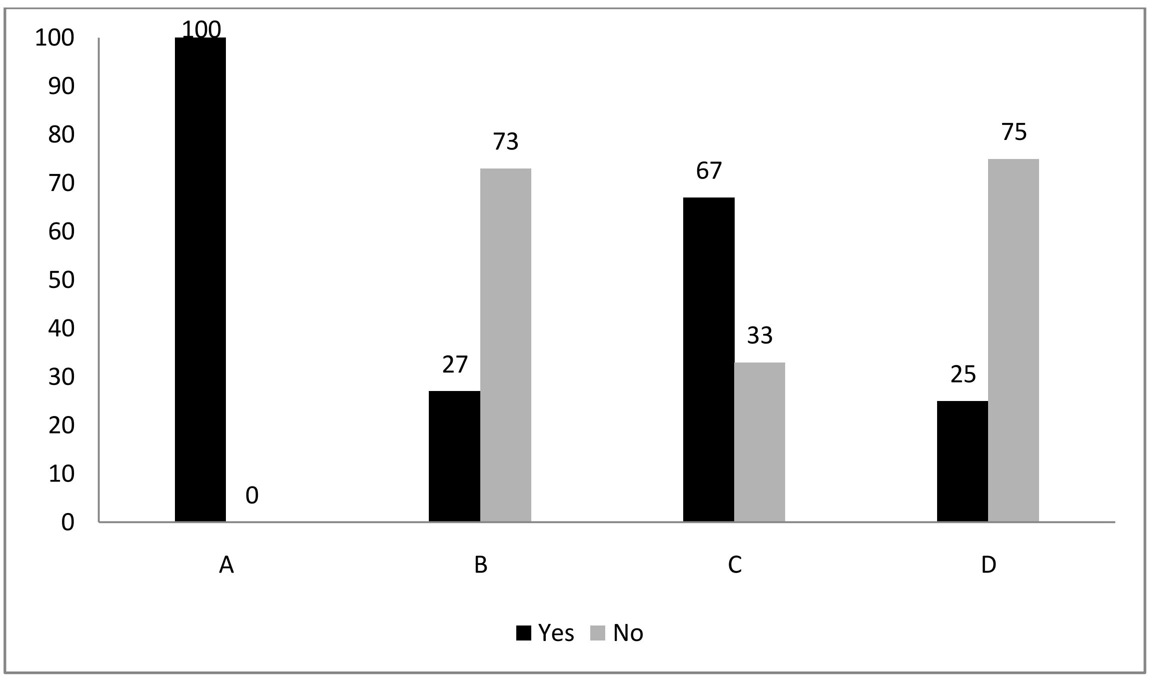
Question: 15

		Sample Size	Percent
A	yes	58	100
	no	0	0
B	yes	36	90
	no	4	10
C	yes	68	100
	no	0	0
D	yes	40	87
	no	6	13
E	yes	38	86
	no	6	14
F	yes	46	96
	no	2	4



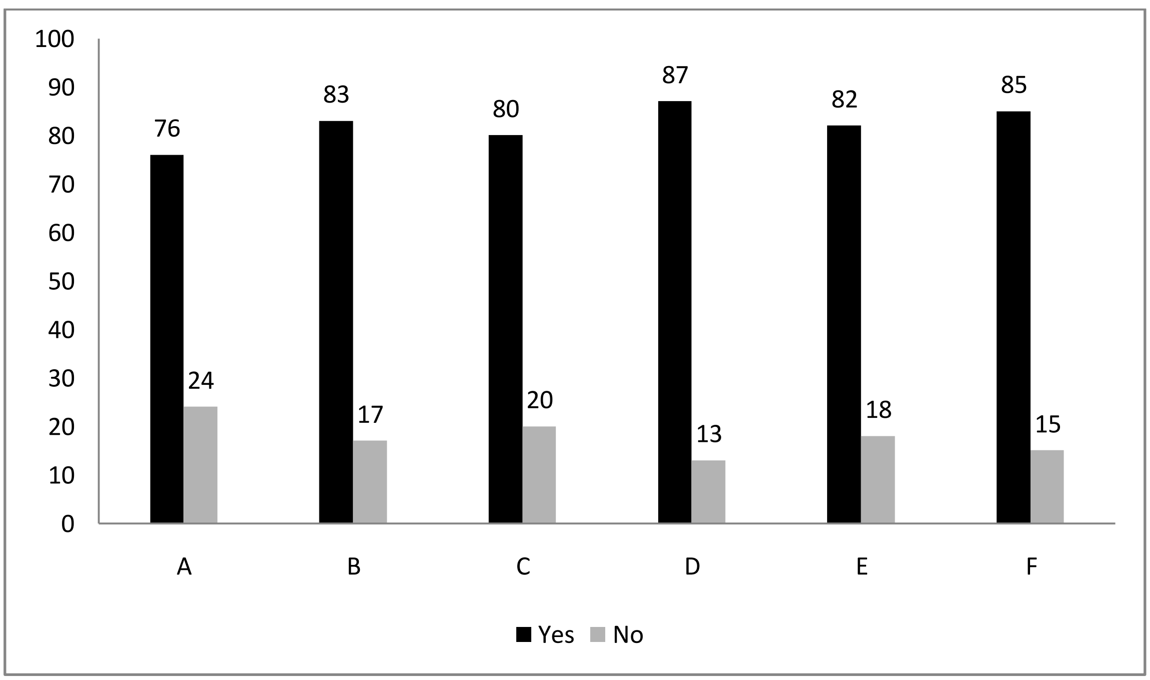
Question: 16

		Sample Size	Percent
A	yes	68	100
	no	0	0
B	yes	6	27
	no	16	73
C	yes	8	67
	no	4	33
D	yes	2	25
	no	6	75



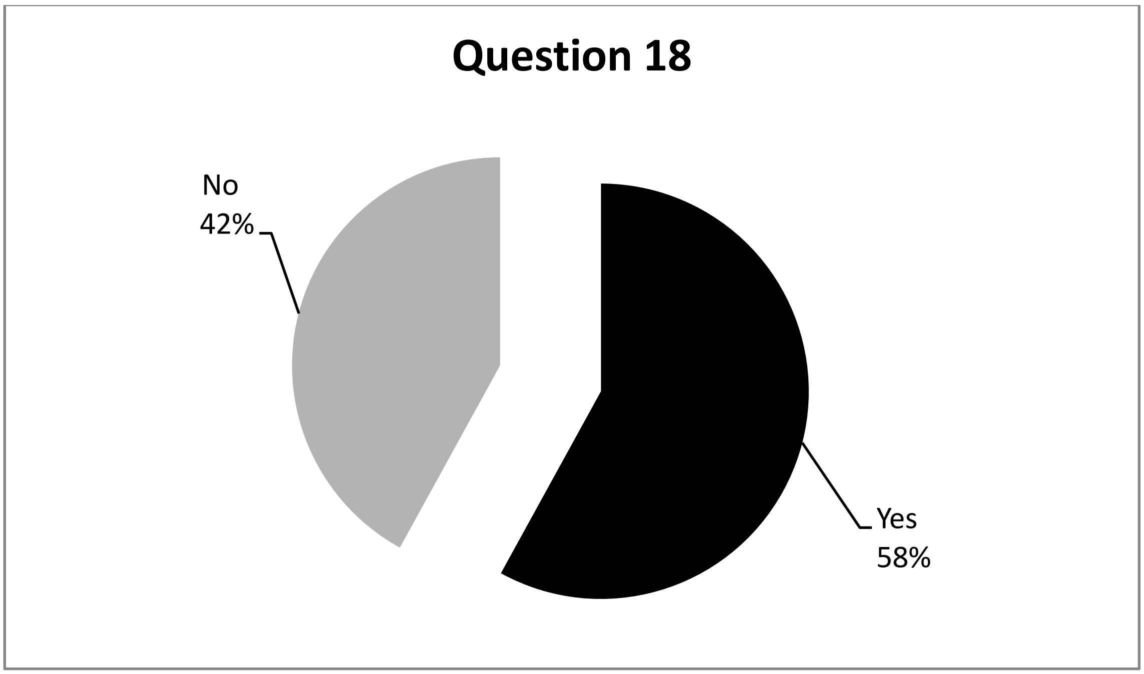
Question: 17

		Sample Size	Percent
A	yes	32	76
	no	10	24
B	yes	40	83
	no	8	17
C	yes	36	80
	no	10	20
D	yes	26	87
	no	4	13
E	yes	18	82
	no	4	18
F	yes	22	85
	no	4	15



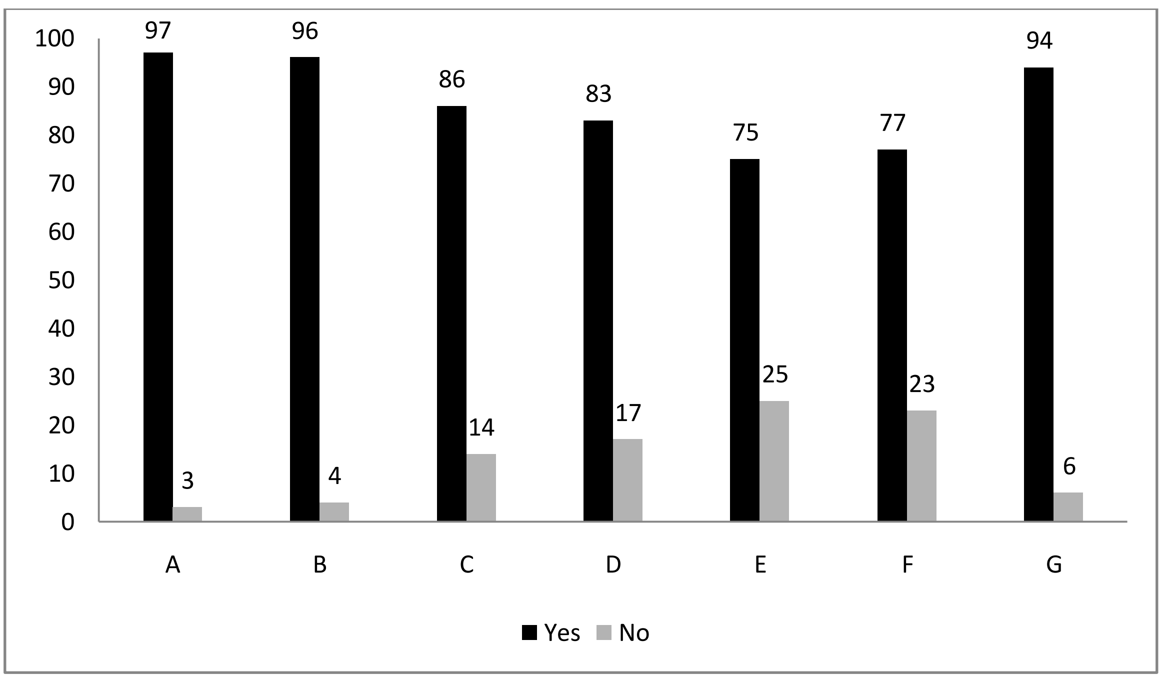
Question: 18

	Sample Size	Percent
yes	22	58
no	16	42



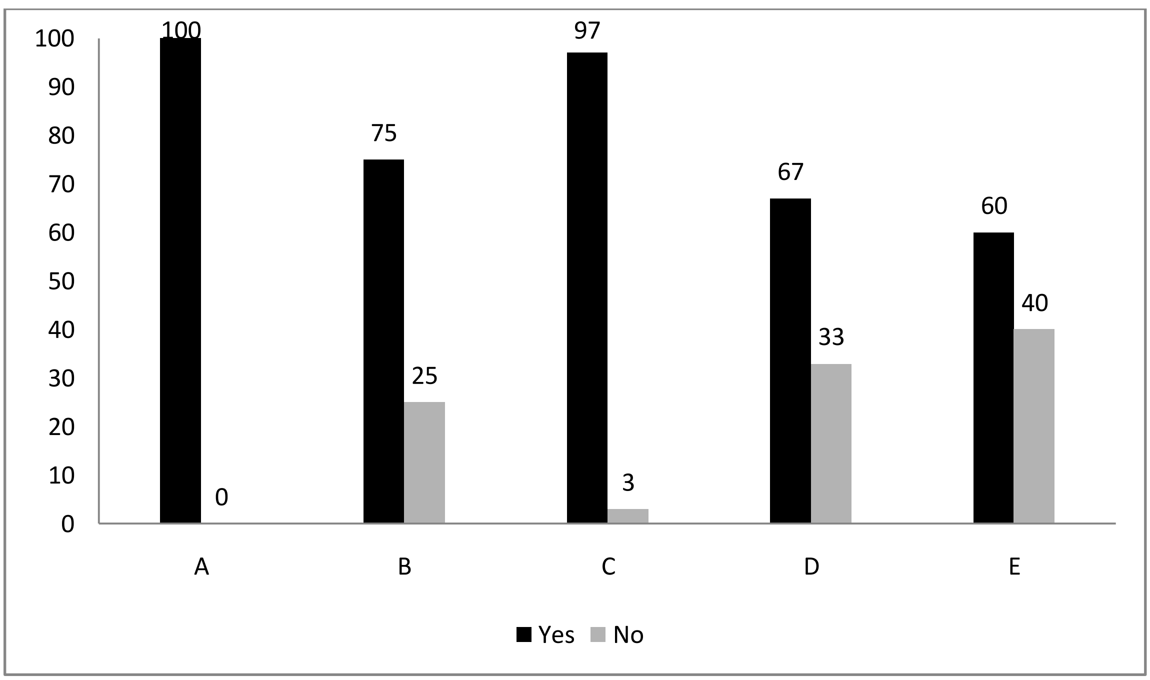
Question: 19

		Sample Size	Percent
A	yes	58	97
	no	2	3
B	yes	54	96
	no	2	4
C	yes	50	86
	no	8	14
D	yes	40	83
	no	8	17
E	yes	24	75
	no	8	25
F	yes	20	77
	no	6	23
G	yes	34	94
	no	2	6



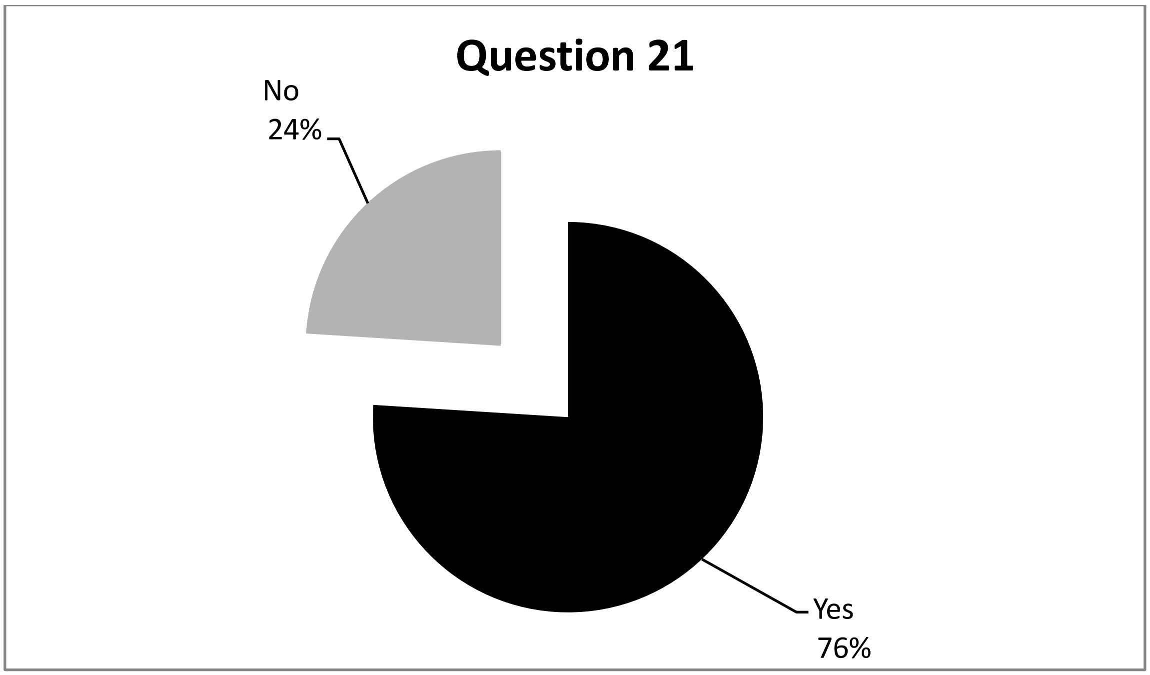
Question: 20

		Sample Size	Percent
A	yes	6	100
	no	0	0
B	yes	6	75
	no	2	25
C	yes	62	97
	no	2	3
D	yes	4	67
	no	2	33
E	yes	6	60
	no	4	40



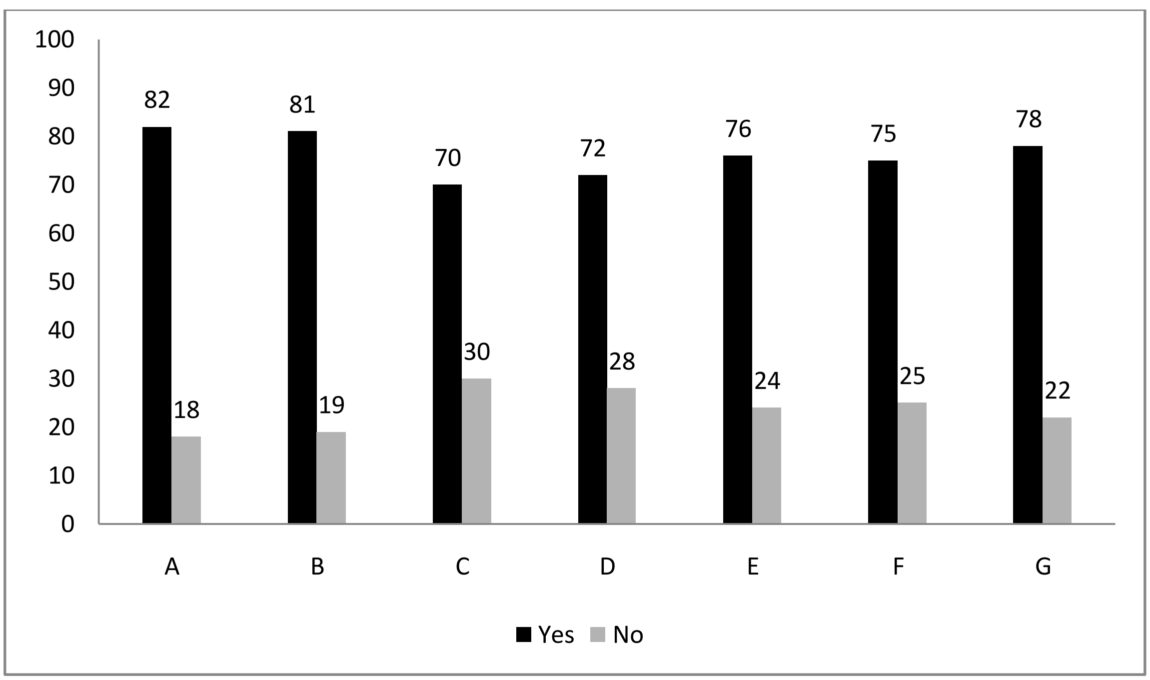
Question: 21

	Sample Size	Percent
yes	60	76
no	20	24



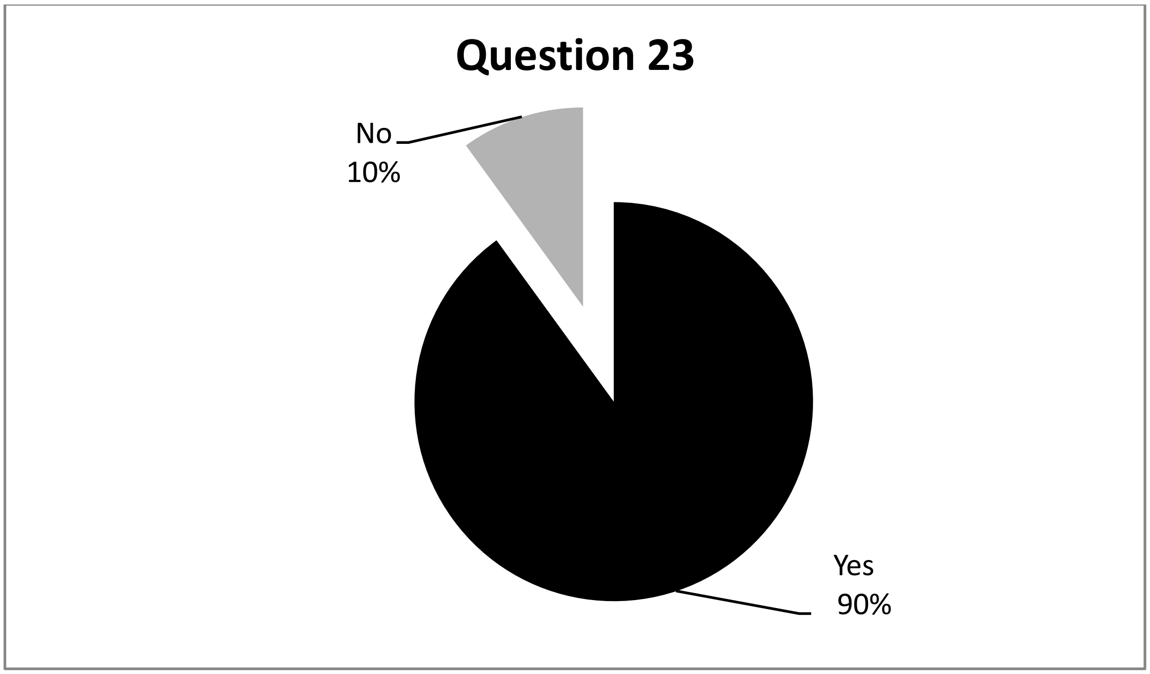
Question: 22

		Sample Size	Percent
A	yes	56	82
	no	12	18
B	yes	52	81
	no	12	19
C	yes	42	70
	no	18	30
D	yes	42	72
	no	16	28
E	yes	52	76
	no	16	24
F	yes	42	75
	no	14	25
G	yes	50	78
	no	14	22



Question: 23

	Sample Size	Percent
yes	72	90
no	8	10



Question: 24

	Sample Size	Percent
yes	78	100
no	0	0