İSTANBUL KÜLTÜR UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

THE COMPARATIVE OF LIFE CYCLE ASSESSMENTS BETWEEN STEEL AND REINFORCED CONCRETE STRUCTURES

Master of Applied Science Thesis

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ABSTRACT

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The major of this study is to understand the influence of considering the lateral load during the design face of the buildings on the CO_2 emissions. Since steel and reinforced concrete structures have been used in a variety of buildings in the United States in recent years, it is critical to examine and perform research on the environmental implications of the designs and materials used in those constructions. This study investigated various multi-story residential structures in the United States with similar functions for this purpose. sixteen of the buildings was constructed with a steel frame and the other thirteen with a concrete structure. Accordingly, to achieve these aims assets of 32 different structures vary considering factors such as structural type, height, location of the structure, and loading scenarios. As this study show that Concrete structures emitted 23% more CO2 than steel buildings. While the results reveal that constructing a concrete building in an A class earthquake area creates 25% higher CO2 emissions than building in a non-seismic region.

Keywords: LCA, Carbon footprint, Athena Impact Estimator for Buildings, Steel Building, Reinforcement building, Earthquake Resistant Design.

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Anabilim Dalı: İnşaat Mühendisliği

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ÖZET

ÇELİK VE BETONARME YAPILAR ARASINDAKİ YAŞAM DÖNGÜ DEĞERLENDİRMELERİNİN KARŞILAŞTIRILMASI

Bu çalışmanın ana bölümü iki bölüme ayrılmıştır, ilki binaların tasarım yüzü sırasında yanal yükün dikkate alınmasının CO_2 emisyonları üzerindeki etkisini anlamaktır. Bu çalışmanın ikinci amacı, hem betonarme hem de çelik yapılar için CO2 emisyonlarını doğru bir şekilde tahmin edebilen yapay sinir ağı modelleri kullanarak hızlı bir tahmin modeli önermektir.
Son yıllarda Amerika Birleşik Devletleri'nde çeşitli binalarda çelik ve betonarme yapılar kullanıldığından, bu yapılarda kullanılan tasarımların ve malzemelerin çevresel etkilerinin incelenmesi ve araştırılması kritik önem taşımaktadır. Bu çalışma, bu amaçla Amerika Birleşik Devletleri'nde benzer işlevlere sahip çeşitli çok katlı konut yapılarını araştırmıştır. binalardan on altısı çelik karkas, on üçü ise betonarme olarak inşa edilmiştir. Buna göre, bu amaçlara ulaşmak için 32 farklı yapının varlıkları, yapı tipi, yüksekliği, yapının konumu ve yükleme senaryoları gibi faktörler dikkate alınarak çeşitlilik göstermektedir. Bu çalışmanın gösterdiği gibi, Beton yapılar çelik binalara göre %23 daha fazla CO2 yayar. Sonuçlar, A sınıfı deprem bölgesinde betonarme bir bina inşa etmenin, deprem olmayan bir bölgede inşa etmekten %25 daha fazla CO2 emisyonu oluşturduğunu ortaya koymaktadır.

Anahtar Kelimeler: LCA, Karbon ayak izi, Binalar için Athena Etki Tahmincisi, Çelik Bina, Güçlendirme binası, Depreme Dayanıklı Tasarım.

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ABBREVIATIONS

DFD: Design for disassembly.

SSD: Sustainable structural design.

LCA: Life Cycle Analysis.

CODES ABBREVIATIONS:

LEED V4.1 GREEN BUILDINGS RATING SYSTEM.

GREEN GLOBE RATING SYSTEM.

ISO 14044 – LIFE CYCLE ASSESSMENT.

ISO 21930 - SUSTAINABILITY IN BUILDINGS AND CIVIL ENGINEERING WORKS.

ACI 318-14 - BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE.

EUROCODE 3-2005 - DESIGN OF STEEL STRUCTURES.

ASCE7-16 - MINIMUM DESIGN LOADS AND ASSOCIATED CRITERIA FOR BUILDINGS AND OTHER STRUCTURES.

CHAPTER 1
INTRODUCTION

1.1 General

Sustainability has been implemented in building construction for over a decade. It has been considered a high priority to design and construct frame buildings amongst specialists associated with structure and development. Sustainability includes important interactions and relationships between environmental, social, and economic standards. Regarding the development area and construction sectors, sustainability identifies with guaranteeing that the structure is economically and environmentally friendly which provides quality and healthy areas for the residents. Despite the value of investigation into the feasible properties of materials and the energy-saving methodologies to sustainable structural design, past research has outlined that sustainable structural design depends on the best possible usage and implementation of structural systems and forms. Likewise, as proposed by past research, the eventual fate of the environment condition needs to represent progressively by considering the system of the building. Architects and civil engineers are continually evaluating their capacity to approach the ideal sustainable design and construction industries. The aim of the industries is to indicate the environmental problem that faces modern culture and try to achieve the goal of finding the solution for those problems by assessing all processes and aspects that are involved in the project. Designers and planners have been provided with some methodologies to design buildings in a way to reduce their ecological footprint and making the building more energy-efficient, water-efficient, and optimizing the environmental impact on the plan and the design. The aspects of the project's materials and systems are directly and indirectly related to the issues that encountering civil engineers to select building systems to be environmentally friendly. According to the Environmental and Energy Study Institute EESI, studies refer to the increase of global temperature because of the Industrial Revolution. The average global temperature has raised up by 0.8 C from 1880 until 2020.

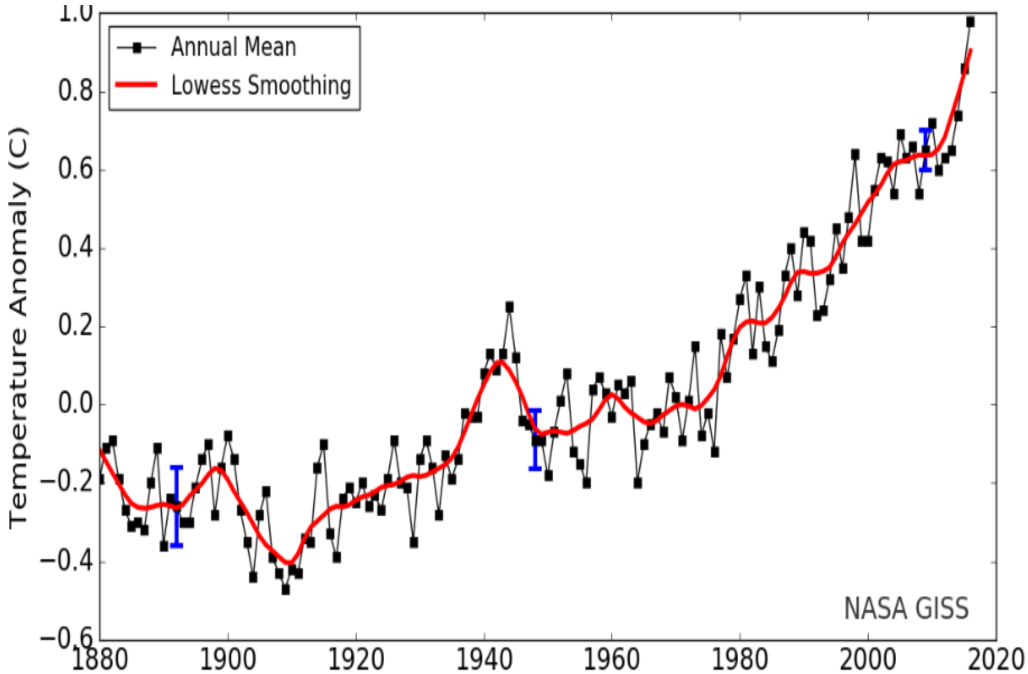


Figure 1.1: The Temperature Index of Land and Ocean [1].

This figure 1.1 illustrates the changes of land and ocean temperature [1]. it shows us the increase of temperature since 1880 to 2020. Since preindustrial times, Global average temperature has raised up above 1 degree Celsius and it still raising up, researchers anticipate that the normal worldwide temperature will rise an extra 0.3 to 0.7 degrees Celsius through 2035.

1.2 Aim of the Study

This study aimed to evaluate the effects resulting from the construction of various concrete and steel buildings under dynamic analysis in the different structural frame types of building using four different types of slabs.

- Giving a reasonable evaluation between concrete and steel systems utilizing LCA.
- Mitigating the impact of concrete and steel structures on the environment.
- Emphasizing the importance of the building frame design approach. The plan views and building sections for all the building types.

The study includes defining the columns dimension, frame structures, type, and the use of the building in a specific location. The selected buildings are subjected to comparing the structural systems, footprint, the effectiveness of stories number, and elevations as well on the environment by following the whole Building Life Cycle Assessment. Finally, applying artificial neural networks to simulate the generating software that can be capable to simulate the outputs of expected impacts on the environments.

1.3 Organization and Scope of the Thesis

This study is including five chapters:

The aim of the first chapter is to provide a general idea with an introduction to the study, and the aim of the current study.

The second chapter provides some outputs of previous studies in a literature review section to define and summarize methods of analysis.

The third chapter gives a methodology and analysis approach; it consists of a summary of definitions of the type of slabs, parameters of the frames, locations, and methodology of design.

The fourth chapter is a description of the case study, explaining the outlines plans used in the thesis.

consists of the result and discussion. This chapter will illustrate the comparison result between steel buildings designs and reinforce concrete ones. The chapter is divided into two parts. the first part will include the result and discussion of no-lateral load subject on the buildings and their impacts on the environment. In the second part, the results of buildings that subjected to pushover will be discussed in terms of lateral load capacity, lateral displacement, and the resulting footprint of carbons emissions.

The last chapter, chapter five, provides the conclusion and suggestions. This chapter finalizes the summary of the analysis methods that are used in the study. The recommendations of the future will be mentioned in this chapter.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This section illustrates the investigation of six literature reviews which have been conducted and been under study for different type of frame. Too many studies and LCA that been also carried out.

2.2 Sustainable Structural design

Sustainable structural design (SSD) was existed and used in early projects, but the term sustainability was not known and not being mentioned until years later.

In 1984 an article about bio brick project was published by Alleman and Berman, the article illustrates how wastewater can be reused to make some material which later can be used in structural works. This way of benefiting from wastewater solved some of society's issues and reduced some energy, However, Sustainability was not mentioned at that period. The term sustainability was mentioned and clearly defined after the Brundtland report in 1987. [2]

Six sustainability principles of construction fostered many civil engineering practices in 1994 by Kisbets. [3]

"Reducing the consumption of resources; maximize resource reuse.

use recyclable and reusable resources; making environments more protected and healthier; ensuring the quality in constructing the environment."

Miyatake was credited with his contribution in publishing the literature in (1996) by pointing out various options and alternatives way for civil engineers to understand sustainable civil construction. He refers to the use of recyclable and reusable resources and converting the process of construction from linear to cyclical construction.

After some time, the accreditation of the role that how structural engineers can achieve sustainability aims and increase the awareness of the effect of structural systems on the environment. Due to the previous papers on sustainability structural design, At the present time, engineers are adopting variation practices of sustainability [4].

Various challenges have come out to challenge the structural engineers to provide a systemic approach to sustainable design.

These challenges have been raised as several questions for discussion on the importance of the role of practices during construction and the materials used for construction so that the aim is to achieve longer life of the facility. And whether the structural design of buildings increases the life span and reduces the consumption of raw materials. SSD opens many questions of the importance of modeling analysis and the strategy used to reach the most appropriate model in terms of the required sustainability standards. There are several aspects and methods which are an integral part of achieving sustainable structural design.

The importance of studying the SSD lies in identifying the gaps and behaviors followed by civil engineers and filling them in all systems and standards for the classification of green buildings.

In another sense, those standards and studies used to reduce the impact of buildings on the environment must fulfill the established and modern expectations for achieving environmental sustainability and reducing wasted energy. Because of the urban space that is growing dramatically. Buildings have become one of the most important sectors affecting the environment and the economy. Sustainable construction improves life and also increases the chance of creating environmental problems and working to fix them.

Environmental studies include a life cycle methodology that relies heavily on the assessment method.

SPBA, which provides a directed approach to environmental and structural design, life-cycle analysis of the structure through an assigned life cycle, and an understanding of the impact of carbon dioxide emissions and energy consumption in structural design. Each of these studies is studied on structural frames under seismic influence. Among the most important of these studies is the study of the effect of energy and gases emitted due to construction and its effect on the environment.

2.1.1 Sustainability and Construction Type:

In structural design, a project's capacity to accomplish its sustainability goals is closely related to the sort of construction it undertakes. The operational and embodied energy of a project and/or structure grows in proportion to its size. As a result, understanding the function structural systems play in sustainability necessitates an examination of the impact that building type (wood, steel, and concrete) might have on a project's sustainable features.

2.1.2 Sustainability and Construction Materials

Construction materials are vital in determining the long-term viability of any design option. Structural steel, cast-in-place reinforced concrete, and prestressed/precast concrete all have distinct properties that contribute to a project's long-term viability. Structures with low energy costs, great durability, minimal maintenance requirements, and substantial amounts of recycled materials are linked with good sustainable qualities.

2.1.3 Review of Life-Cycle Analysis Computer Programs

Sustainability-modeling tools have been built in order to examine the economic and environmental effect that design options can have on a project. These programs aim to compare the sustainability of many design possibilities in order to find the most sustainable solution. The Athena Impact Estimator v5.3 is three programs that are particularly useful for analyzing structural design sustainability. This program tackles the issue of measuring sustainability in a variety of ways.

The methodology of sustainable structural design is divided into 5 methodologies:

1.) Minimizing Material Use

Total structural material reduction is one objective of sustainable structural design and optimizing a structural model using a single material type is another way to cut down on the quantity of material used.

2.) Minimizing Material Production Energy

A technique for structural sustainability includes decreasing the amount of energy and natural resources necessary for the manufacture of building materials, in addition to the design of the structural system itself. A manufacturing energy cost exists for all building materials (cast-in-place reinforced concrete, prestressed concrete, steel, wood, masonry, and so on). This cost can vary from year to year and by area, and it can be influenced by global market conditions as well as environmental regulations.

The evaluation of the energy costs necessary in the collection, refining, and mixing (among other things) of raw materials is where sustainability enters the material manufacturing process.

Furthermore, in this technique, sustainability is based on the decrease in overall energy costs that may be accomplished in order to create materials with the same, or similar, structurally useful material qualities as present production methods.

3.) Minimizing Embodied Energy

to minimize the energy required for the structural process as the emphasis moves to the effective use of the natural environment, this technique opens the door to more sustainable designs (regional thermal qualities, geothermal wells, waste recycling systems, wind turbines, solar panels, etc.)

4.) Life-Cycle Analysis/Inventory/Assessment

The Life-Cycle Analysis is a typical method used by design professionals to examine and quantify the sustainability of a project (LCA). The Life-Cycle Inventory (LCI) and Life-Cycle Assessment (LCAs) analytical methodologies are used in the same way. These methods are frequently used to support or qualify a design decision's net-cost-to-benefit ratio or economic impact. Designers and engineers collaborated to use these models (outlined by ASTM standards E 964-06, E1057-06, E1074-06, E 1121-07, E1185-07, and E2204-05) to assess the long-term qualities of various structural system components. These standards outline the methodology for identifying and assessing multidimensional aspects of a decision including several metrics.

5.) Maximizing Structural System Reuse

The Life-Cycle Analysis is a typical method used by design professionals to examine and quantify the sustainability of a project (LCA). The Life-Cycle Inventory (LCI) and Life-Cycle Assessment (LCAs) analytical methodologies are used in the same way. These methods are frequently used to support or qualify a design decision's net-cost-to-benefit ratio or economic impact. Designers and engineers collaborated to use these models (outlined by ASTM standards E 964-06, E1057-06, E1074-06, E 1121-07, E1185-07, and E2204-05) to assess the long-term qualities of various structural system components. These standards outline the methodology for identifying and assessing multidimensional aspects of a decision including several metrics.

2.3 The embodied energy of Steel and Concrete Industry

This section illustrates the impact of concrete and steel industry concerning both to know their emission of energy for both materials on the environment and to illustrate previous studies concerning the investigation of the specific information that can be related to the environmental impact.

2.3.1 Impact of Steel Industry on Environment

The manufacturing process of steel and metallic materials that occupies a large area in the field of industry at the present time. It is also one of the largest energy-consuming operations. Carbon dioxide is produced in large quantities by the factories that produce steel, and since the steel industry relies heavily on iron, this gas is produced from the reduction of iron ores in blast furnace and sponge iron factories. In addition, it is produced from the use of fossil fuel energy in processes Heating, it is worth noting that the coal used in energy production produces 90% of carbon dioxide [5].

The iron manufacturing process releases harmful gases to the atmosphere, including sulfur dioxide, which emissions of sulfur dioxide are mainly related to the combustion of sulfur compounds present in the sintering materials, which can also be included in the main as a result of the use of coke dropping. Granules, and firing in coke ovens. The emission of sulfur dioxide in waste gases from reheating and annealing furnaces depends on the sulfur content in the used fuel. This process also creates nitrogen oxides in factories where coal is used, electric arc furnaces, and heating furnaces, and since the iron and steel industry relies heavily on high temperatures, it is difficult to avoid these oxides since nitrogen is present in the air.

Carbon dioxide plays a fundamental role in the sequence of the carbon cycle in the earth, and in this cycle carbon dioxide moves from the atmosphere, accompanied by a difference in the temperature of the atmosphere and climate change, directly and indirectly, and climate change is a crucial issue in our time. Because of its wide-ranging effects, such as changes in temperature, precipitation rates, and weather patterns, which threaten global food production, in addition to rising seas and oceans levels, which leads to an increase in the risk of floods, and this in turn negatively affects Both human health, natural and ecological systems, water resources, and human settlements,

2.3.2 Impact of Concrete Industry on Environment

The production of cement is considered as one of the biggest energy consumptions and as one environmental concern. Also, it is one of the most energy-dense in comparison to other industrials manufacturing processes. The fuel which is consisted of mining and transportation of the raw materials is included in energy consumption. 1,758 kWh is the energy needed to produce a ton of cement [6]. The heavy industry leans on coal which leads to high emission of CO_2, Sulfate, nitrous oxide, and other pollution. A huge part of electricity is generated from coal too and most of the consumption of energy is generated for producing cement for operating the cement kilns. Wet process kiln consumes more energy than Dry process kiln because most of its energy generated to take the moisture off. Air heating is used in modern dry ovens to work on the principle of recovering the waste heat from the boiler flue gas that is provided by the exhaust gases in the oven stoves.

An adapted dry process kiln can utilize up to 50% which is less than the wet process one. Some separate combustion vessels are used in other dry process kilns. Calcination starts before the components are transferred to the rotary kiln. This technology may have a higher energy efficiency than an oven that has a preheater. Before materials are transferred to the rotary kiln, with high energy efficiency technology from the oven that contains the preheater, the calcination process begins Since manufacturing cement is considered as an extremely energy consumer because high temperature is needed to heat the cement in the cement kiln. However, the cement kiln has also some advantages to reduce the hazard waste by using them as fuel for the kilns. A lot of waste fuels can be utilized in cement kiln such as car oil, motor oil spent solvents, paint residues, printing inks, cleaning fluids, and wasted car tires. All these materials can be burned without leaving any remaining parts because of the high temperature with extremely low pollution emissions.

The safest way for disposing and distracting chemical components is via cement kiln.

According to the Portland cement association, one million tires can be burned yearly via a single Portland cement kiln. It seems that concrete manufacture is better than concrete production because of the less energy-intensive of concrete components (Crushed stone, sand, and water)

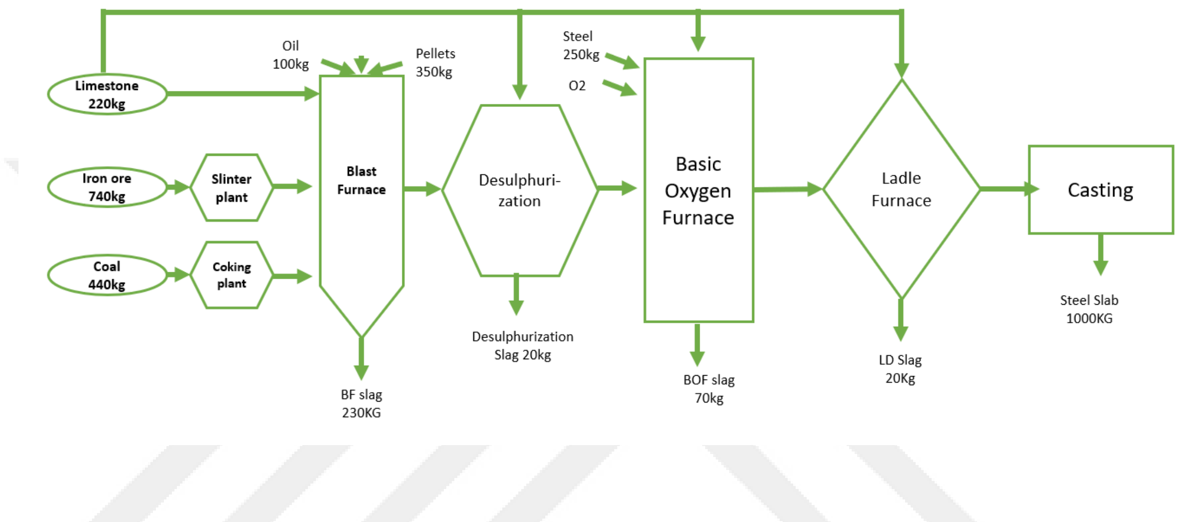


Figure 2.1 : Schematic Diagram of the Steel Manufacturing Process [7]

During cement production, calcining limestone and combustion of fossil fuels are considered the two sources of carbon dioxide emissions. 3/4
CO_2/ton of cement is produced during the combustion of fossil fuels to feed the rotary kiln. Adding these two sources of cement production, for each one ton of cement, it produces 1.25 tons of CO_2. This emission emits into the air causing some impacts on the environment [8].

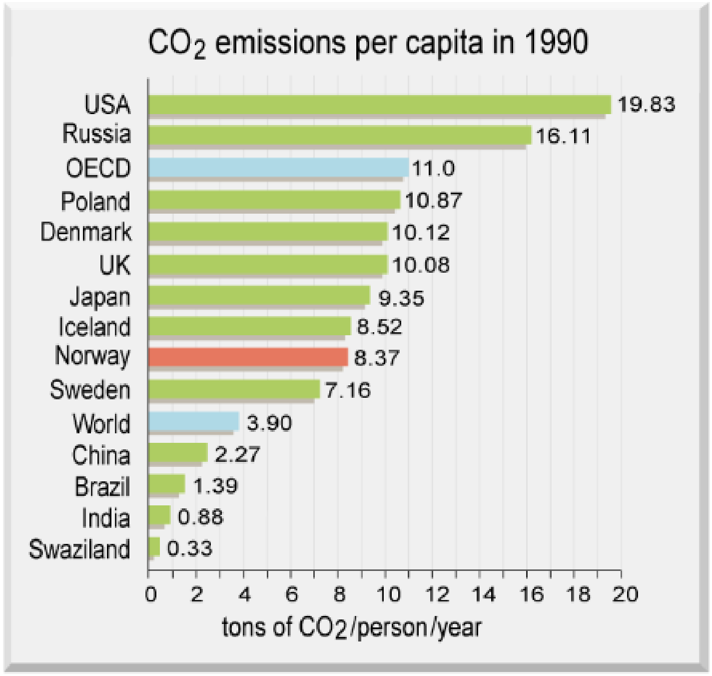


Figure 2.2: CO_2 Emission 1990[9].

The emissions of CO_2 which been described in the figure 2.2 in 1990. The use of fossil and fuel consumption can be the factor of the CO_2 emission as by the production of cement also Cement Kiln has a significant role in generating CO_2.

A huge amount of air emissions aside from CO_2 emission is produced by cement and concrete manufacturing. This kind of production plays a significant role in increasing air pollution emissions. The most significant emission is dust which is the most visible among these pollutants. Specks of dust participate by 360 pounds per one ton of cement production [9].

The majority of that comes during treating raw materials, grinding cement clinker, and packing and loading the ready to ship. The ideal way is to put place wasted cement which comes out during producing into the process again. By utilizing mechanical collectors, fabric filters and precipitators.

Recycling dust does cost very. Because the alkalinity should be reduced and treated. Some other cement kilns dust is utilized for agriculture purposes by treating the soils and some of the cement dust is used for filling land on site.

Cement manufacturing is not the only source of dust, dust is also generated in a concrete process and transportation. The vast majority of dust comes to aggregate, sand, transporting materials and storage, during mixing the materials and dust comes from unpaved roads.
fugitive dust can be controlled by hoods, curtains, water sprays, and covered chutes.

2.4 Analysis of Results for Both Steel and Reinforced Buildings

1- Environmental impacts of building structures in Taiwan (2011)
2- Comparison of LCA on steel- and concrete-construction office building in China (2008)
3- Comparative Life Cycle Assessment of Steel and Concrete Construction Frames: A Case Study of Two Residential Buildings in Iran

2.5 Discussion on Literature Review

2.5.1 Environmental Impacts of Building Structures in Taiwan (2011)

In Taiwan, there is three types of material which been utilized. Concrete and steel materials and there is some limited number of wood structure are conducted in Taiwan. The study of Sheng-Han Li, and Hasim Alton investigates the benefits of using different type of structures and compare between each other by developing in terms of embodied energy and the buildings emissions.
The process of Steel, concrete and wood went into four stages (material extraction, road and marine transportation, and manufacturing). Environmental impacts of materials in terms of embodied energy and CO_2 emissions are illustrated. Steel structure has the highest environmental burdens and manufacturing process accounts for 82% and 88% of the total CO_2 emissions. In term of SSD, concrete building has 46% higher energy consumption than the steel one and among the other structure buildings [10].

2.5.2 Comparison of LCA on Steel- and Concrete Construction Office Building in China (2008)

The result from Xu Zhang study between the two buildings illustrates confirm that the concrete building has less energy consumption than the concrete one regarding of energy consumption and environmental impacts over a lifetime of 50 years. The energy consumption of the steel building is %8 higher than the concrete building. The NOx and Sox urban emissions of the steel building are higher than the concrete building by %6.2 and %1.7, respectively. Comparing the study between Xu Zhang, Amir Oladazimi and Sheng-Han Li. Xu Zhang found that the concrete consumes less energy than steel. However, Amir Oladazimi and Sheng-Han Li's studies show that concrete buildings have higher consumption than steel buildings. It's good to see that the location of the construction sites, factors, and structural design used in their studies are different [11]. Also, the steel structure has been determined to account for 75.1 percent of the energy consumption in the life cycle in comparison to the LCA of the reinforced concrete building, which accounts for half of the environmental emissions. So, as a result, steel-framed structures outperform concrete buildings in terms of life cycle energy consumption and emissions. On the other hand, the average heat transfer coefficient of the steel frame building casing is greater than the heat transfer coefficient of the concrete frame building casing, due to the strong thermal conductivity of steel. As a result, the life-cycle energy consumption of the steel frame structure and the environmental emissions of air conditioning during the use phase are higher than those of other building types. As a result, the steel building's life-cycle energy consumption and environmental emissions are somewhat higher. The steel frame building's energy consumption and emissions into the environment if the heat preservation of the steel frame building can be improved, the energy consumption during use will be reduced.

2.5.3 Comparative Life Cycle Assessment of Steel and Concrete Construction Frames: A Case Study of Two Residential Buildings in Iran

The study shows the comparison between two building (steel and RC building) which took place in Iran, the study was focused on air pollution, water pollution and land pollution, the total pollution of concrete building was 5.75E+08 kg CO_2 eq which 61% more than the steel building contributing of the total pollution. The Concrete building has 9.12E+06 kg CO_2. However, the steel has 6.88E+06 [12].

In regarding to the face design of steel and concrete building, this study took place in Iran to determine the LCA and the environmental impact of the steel and concrete structure. The structural face took into consideration in a way to understand the better designing and having a clear version between both reinforced concrete building and steel structural building,

The data necessary for the various stages of the two buildings' life cycles were acquired from multiple sources. The data for the construction stage (including the bill of materials for the two frames) was collected from the designers and contractors of the structures. Figure 2.5.1 and 2.5.2 shows the main layout of the two construction frames. Data for raw material procurement, material manufacture, and end-of-life phases were gathered from both worldwide (such as international standards and guidelines) and local (such as national standards, guidelines, and industry reports) sources. The two faces of steel design were shown in the study as to compare the evaluation between both steel structure and reinforced concrete one.

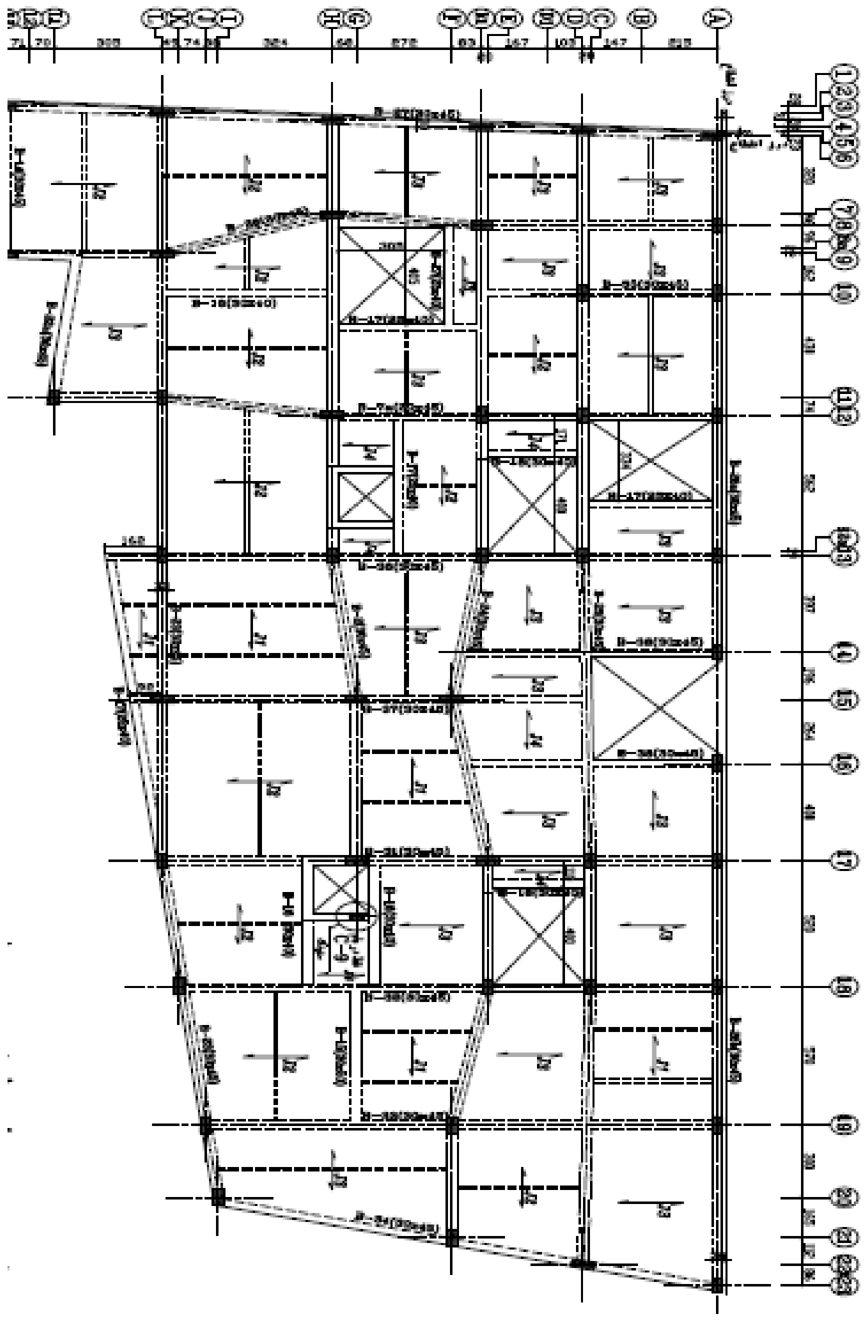
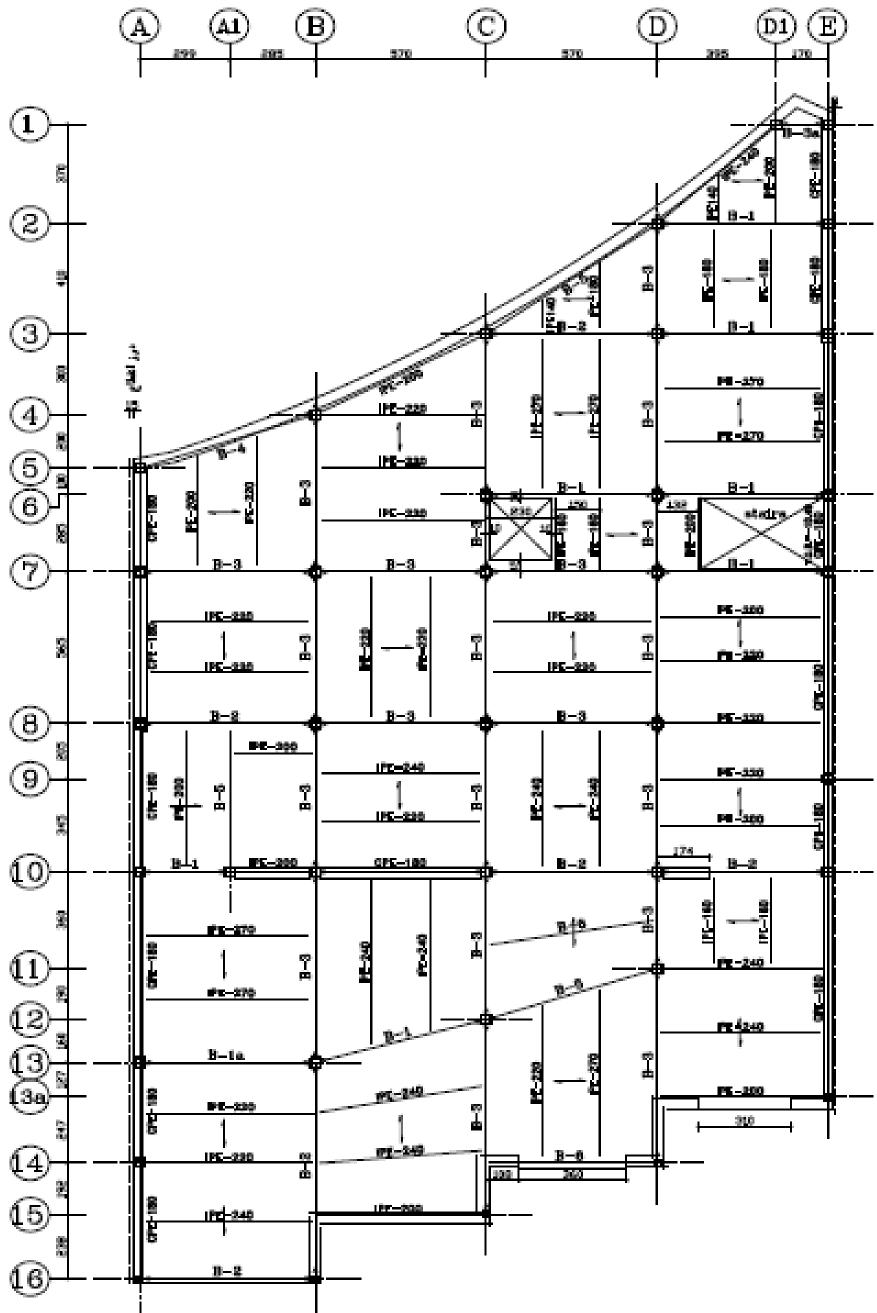


Figure 2.5.1: Concrete Assembly [12].



(b)

Figure 2.5 1: Steel Assembly [12].

2.6 Review of Life-Cycle Analysis Computer Programs

Figure 2.6.1: Screenshot of Athena Impact Estimator 5.4

The software which has been used to evaluate and design buildings' lifecycle-based environmental assessment is Athena Impact Estimator 5.4 for the analysis of the whole building. It allows comparing the effects of the buildings during the construction design on the environment. The type of buildings which and assemblies can be added manually to the software as the construction site location can be written manually. The estimated input of energy which can be the result of CO_2 due to the transportation has been restricted. The "end-of-life" feature allows calculating the energy which is needed for the demolition of the buildings. The main use of the software is to convert the operating energy to the primary energy to be able to compare environmental effects of the primary and operating energy over the building’s life via calculating the emissions of CO_2.

Since the case study is in the USA, the Athena Impact Estimator for Buildings software in the United States allows evaluating the whole building by adding assemblies into the projects.

The software methodology of life cycle assessment (LCA) is recognized globally.

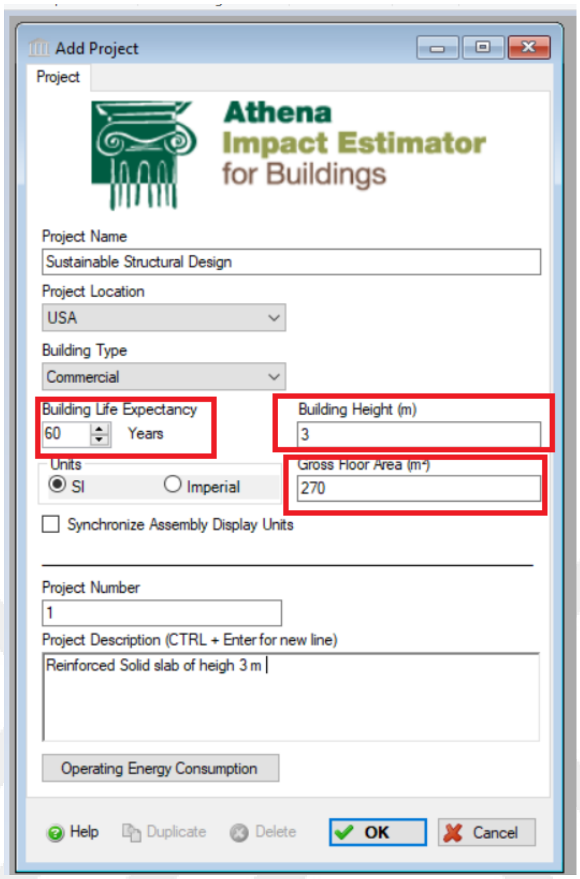


Figure 2.6.2: Screenshot of initial input for the new project by using Athena Impact Estimator 5.4

In the icon shown in Figure 2.6.2, the location of the project is set to "USA." Also, the type of the building has been sat to commercial as a "Building Type." In the figure 2.6.2 the building life span has been selected to 60 years, and the next input beside it is displayed in a red rectangular shown the building height and the gross area. The initial inputs for the building height are 3.6.9.12m while the gross area of the building is 270 m. As the unit of SI Unit been chosen.

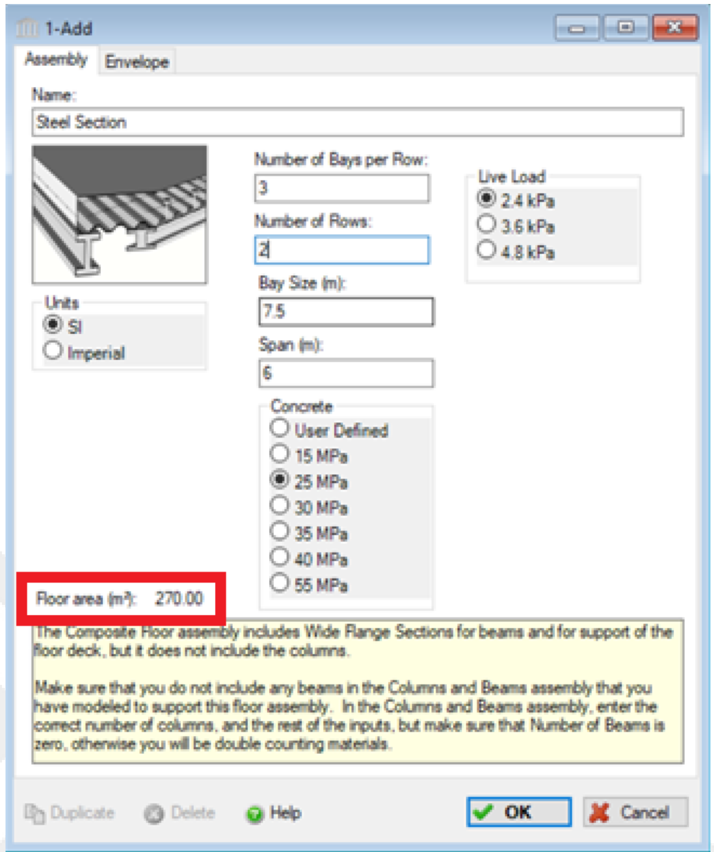


Figure 2.6.3: Screenshot of interface for “Composite slab” in Athena Impact Estimator V5.2

Display on Figure 2.6.3 is a composite slab of the steel structure which is taken into consideration. In order to display the input screen, the “Editing”, “Add Assembly” then by clicking “Floor” and then “Composite floor” One highlighted box has been shown named the floor area, this is calculated automatically after inserting the data needed in boxes “Number of Bays per Row”, “Number of Rows”, “Bay Size” and “Span”

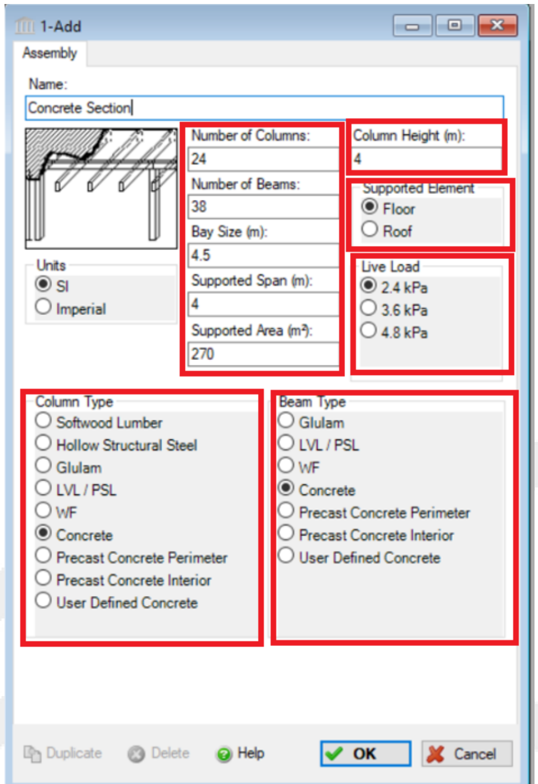


Figure 2.6.4: Screenshot of "Mixed Columns and Beams" in Athena Impact Estimator v5.2

In the input modal shown in Figure 2.6.4. The highlighted boxes "Number of Columns" were set to 24 Columns," Number of Beams" were set to 38 beams while "bay Size" were set to 4.5m and "Supported Span" to 4m. As the project is based on reinforced concrete building. The Beam and columns were chosen as concrete.

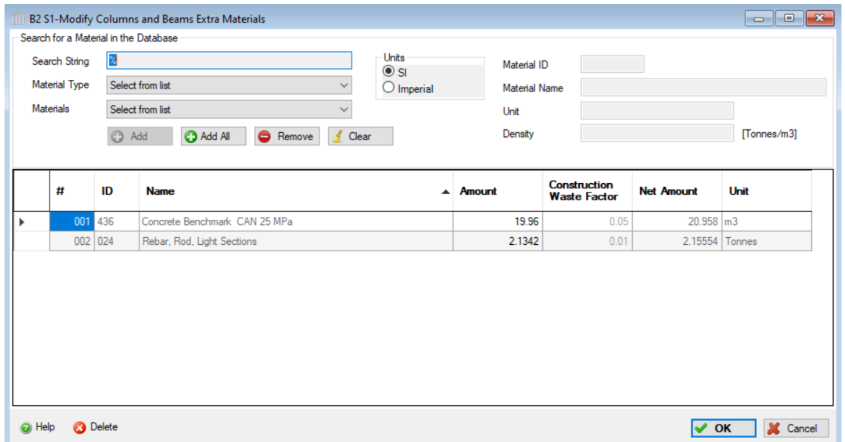


Figure 2.6.5: Screenshot of "Modify Columns and Beams Extra materials" in Athena Impact Estimator v5.2

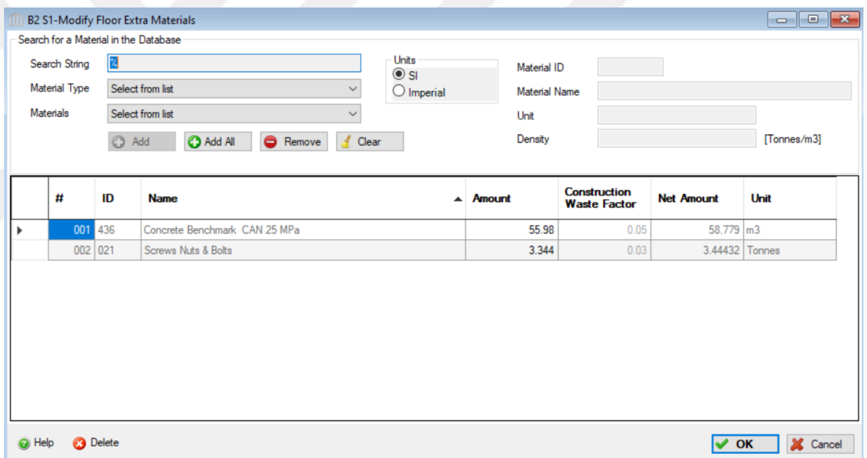


Figure 2.6.6: Screenshot of "Modify Floor Extra materials" in Athena Impact Estimator v5.2

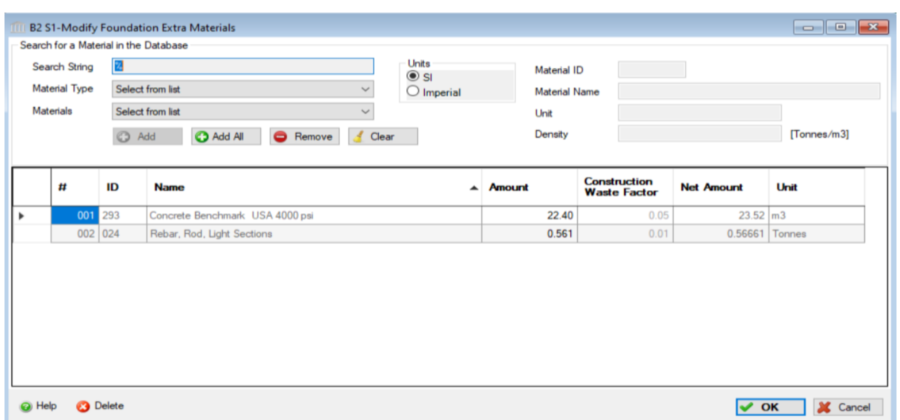


Figure 2.6.7: Screenshot of "Modify Foundation Extra materials" in Athena Impact Estimator v5.2

Because this study's project is complicated and has varying slab dimensions. As a result, selecting "Mix Columns and Beams" and "Composite Slab" for modeling is not a convenient approach. So, the input was modified as extra materials as the Figure 2.6.5, Figure 2.6.6 and Figure 2.6.7. All the input data has been mentioned in Table 4.13 and Table 4.16.

2.7 LCA Software and Metrics

Results of Life Cycle Inventory shows:

Consumption of the total and primary energy.
Resource Use
Land Emissions
Water Emissions
Air Emissions

LCA Measures:

Acidification Potential
Non-Renewable Primary Energy
Eutrophication Potential
Global Warming Potential
Fossil Fuel Consumption
Total Primary Energy
Smog Potential
Ozone Depletion Potential

2.8 Acidification Potential (AP)

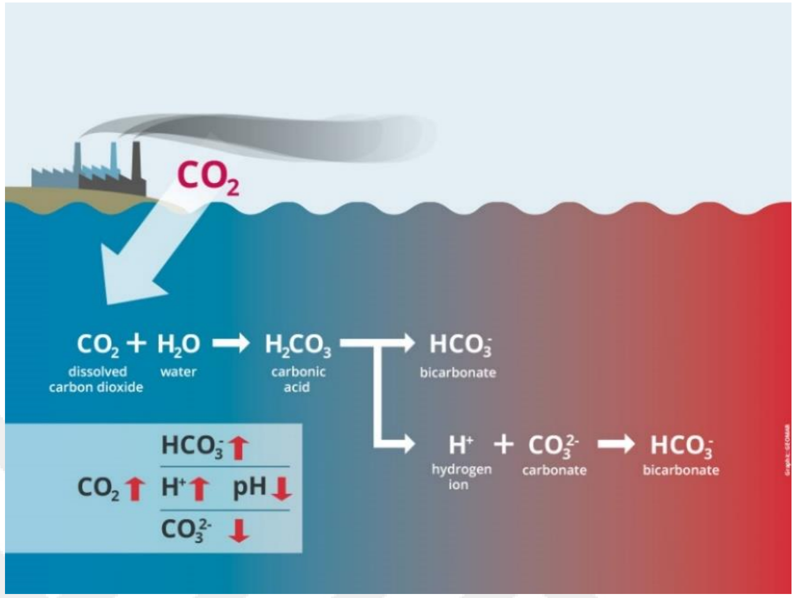


Figure 2.8: Impact of Acidification Potential (ap) [13].

Acidification happens when the seawater absorbs carbon dioxide (CO_2). The PH of the water is reduced due to the chemical reaction between carbon dioxide (CO_2) and Dihydrogen monoxide (H2O) as the formula is shows [13].

CO_2 + H2O ↔ H2CO3 ↔ H+ + HCO3–

(Carbon dioxide + water ↔ carbonic acid ↔ hydrogen ions + hydrogen carbonate ions)

This reaction resulting in bicarbonate ions:

CO_2 + H2O + CO32- 2↔ HCO3–

(Carbon dioxide + water + carbonate ions ↔ bicarbonate ions)

When high levels of NOx and SO2 are approached, acidification seems to have a regional rather than global effect on human health. The AP of water or air emission is calculated using the SO2 equivalence effect on mass.

2.9 Aquatic Eutrophication Potential

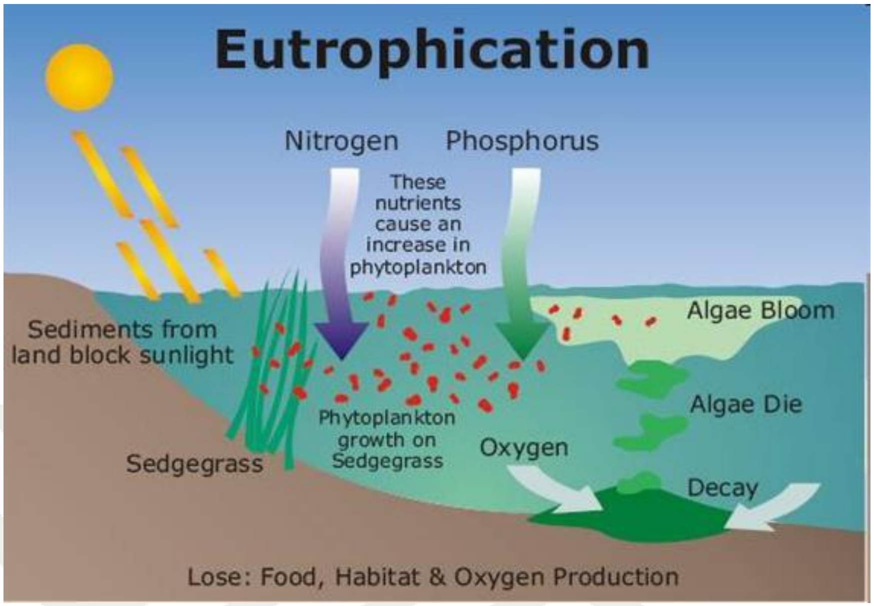


Figure 2.9: Impact of Eutrophication [14].

Eutrophication is a result when nitrate and phosphate are added to the water to increase the number of aquatic photosynthetic plant life. the elevated macroalgal formation, growing sedimentation and, oxygen loss in lower water levels, also it might lead to the death of fish. The nitrogen (N) calculation result is expressed on an equivalent mass [14].

2.10 Global Warming Potential (GWP)

The capacity for global warming acts as a benchmark. One of the most widely known LCIA definitions is the technique and research behind the GWP estimation. The GWP would be expressed as the equivalency of CO_2 in kilograms or tones CO_2 equivalent.

The general reference point for global warming or greenhouse gas effects is carbon dioxide. Many other greenhouse gases have a "CO_2 equivalence effect," which is essentially double carbon dioxide's greenhouse capacity (heat-trapping capability). Because of the reactivity or stabilization of the different contributing gases in the atmosphere over time, this effect has a time horizon.

CO_2 Equivalent kg = CO_2 kg + (CH_4 kg x 28) + (N_2O kg x 265)

based on physical science, the report of climate change in 2014 that was conducted nine of the most common factors of global warming potential are (Nitrous Oxide, Methane, HCFC-141b, HFC-134a, Sulphur Hexafluoride, CFC-11, CFC-12, HCFC-22, and HCFC-142b.

Although energy combustion is the primary source of greenhouse gas pollution, these emissions don't often be calculated due to the complexity during the manufacturing stage but it's necessary to calculate the CO_2 emissions process during the production of steel and cements and calculate the other relevant factors that can be a resultant global warming potential signal.

2.11 Human Health (HH)

Due to the EPA, the process of the diesel and fuel combustion can result many particulate objects with different sizes (PM10 and PM2.5) which have some impacts on the human health because of these matters on the respiratory of humans causing some disease such as asthma and deteriorate the branchiest and so on.

2.12 Ozone Depletion Potential (ODP)

The ozone layer is depleted by increasing the emission of substances such as halons, hydrofluorocarbons, and CFCs, which increase the depletion of substances contributing to the protective ozone layer within the stratosphere with respect to CFC-11 and the correlation is calculated between the effect of CFC-11 to its equivalent mass.

2.13 Photochemical Ozone Formation Potential (Smog)

Smog is a mixture of fog and smoke from cars and factories, and is a type of air pollution, consisting of nitrogen oxides, sulfur oxides, ozone, smoke and other particles, and this fog is one of the aspects of pollution caused by human activities, as the main reason for its formation It refers to coal combustion, industrial emissions, forest fires and the resulting photochemical reactions, and it can be classified into two parts; Summer smog and winter smog [15]. and can also be classified into two other parts, namely sulfur smog and photochemical smog [16]. This problem became common, and the resulting damage to humans, buildings and vegetation was first noted in the nineteenth century. In European cities, because of the renaissance of the Industrial Revolution [17]. The “smog” indicator is expressed on a mass of equivalent O_3 basis.

2.14 Total Primary Energy

The total primary energy contains all kind of energy either the direct or indirect energy, the embodied energy which used for extracting the row materials and for transporting them into a construction building. The calculation of the impact of direct and indirect energy are linked to the LCA stages: Processing, transporting raw materials, manufacturing, and delivering.

Primary Energy includes:

- fossil fuel consumption
- renewable biomass
- water/ geothermal /renewable solar/wind/
- non-renewable nuclear
- feedstock biomass

The Energy Consumption in the life cycle Inventory are:

- Hydro
- Diesel
- Feedstock
- propane
- Heavy Fuel Oil
- Coal
- Non-Hydro Renewable
- Gasoline
- Natural Gas
- Wood
- Nuclear

2.15 Non-Renewable Energy

The energy type of Nonrenewable energy which includes the nuclear energy and fossil fuel energies can be considered as the (Total energy/fossil or nuclear energy)

- The Energy Consumption in the life cycle Inventory are:
- Diesel
- Feedstock
- Natural Gas
- Nuclear
- Coal
- LPG (propane)
- Heavy Fuel Oil
- Gasoline

2.16 Fossil Fuel Consumption

Fossil Fuel Consumption is a subtotal of Total Primary Energy, by energy type, which includes all fossil fuel energies.

The Energy Consumption in the life cycle Inventory are:

- Coal
- Diesel
- Heavy Fuel
- propane
- Natural Gas
- Gasoline
- Feedstock

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this section detailed discussions on the material properties used in the case studies and program development stages will be provided. Furthermore, the research strategy followed in the study will be highlighted.

3.2 Description of the Assessment Method

The study includes evaluating the side effects of concrete and metal structures with different types of panels for concrete slabs, which includes studying the energy produced for each of the stages of building materials production and transportation to the site and the use of drilling and construction equipment. Two methods of evaluation have been included through quantitative analysis of the mechanism of inputs and outputs to obtain the required analyzes for these processes. The required data are obtained from statisticians in charge of factories, and they have a direct relationship with the manufacture of materials required for construction. It is taken into consideration that there are two factors that assess the direct and indirect environmental impacts from the stage of manufacturing, transportation, and construction on the environment. Access to that required information may require a long time and a high cost to collect that data. Therefore, carbon dioxide emissions and energy consumption are assessed by predicting direct and indirect impacts through analyzing the economic inputs and outputs of the building.

There are three harmful emissions produced during the life stage of the structures and they are Cho, Na, and CO_2. These emissions are assessed by analyzing the direct and indirect inputs and outputs. The largest amount of data is collected to enhance the study of input and output analysis, which is widely applied in America and other countries.

The next method, a process analysis is used which is based on the study of carbon dioxide emissions and energy consumed during the production process on a bottom-up approach. This study cannot be obtained if the economic input and output data are not available. This assessment is following ISO 14044 standards for sustainability analysis by studying carbon dioxide emissions from inputs and outputs available at the statistics centers.

The approach of studying and comparing the emission of influencing gases through the pre-manufacturing method, which adopts that method by several countries to calculate the effect of gases on global warming and ozone during the construction and building process by setting product system boundaries to accurately assess the targeted services.

3.3 System Boundary

The limitations of the system considered in this study and the aim of which are to determine the emissions of gases during the construction stages, which are divided into four stages.

The first stage: the stage of manufacturing building materials, which is carried out through statistical data to know the amount of greenhouse gases produced during that process of supplying and manufacturing raw materials.

Stage Two: Transportation of Building Materials. The amount of energy generated during the transfer process from the factory to the warehouse is calculated until reaching the construction site.

Stage Three: The construction process and transportation of workers and equipment

Fourth Stage: Demolition and transfer of materials to landfill and disposal.

The standards and sections correspond to the standards of ISO 14044 and ISO 21930 for the process of building concrete structures for the different slabs in this study.

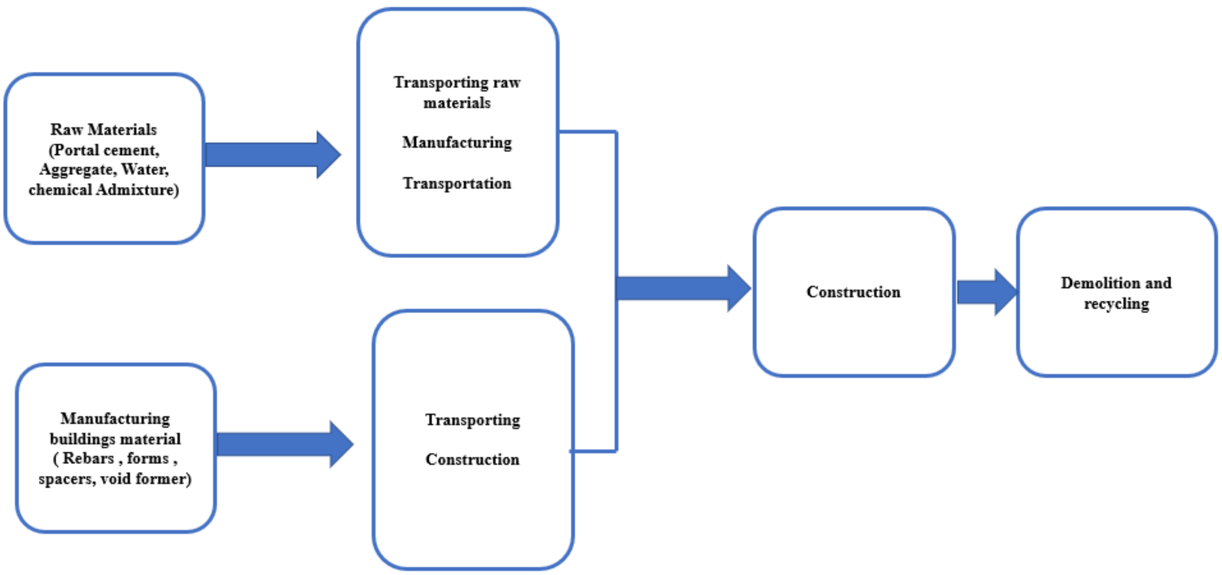


Figure 3.1: System Boundary

3.4 Quantification Method of the Carbon Dioxide Emissions

By calculating the energy produced by carbon dioxide emissions during the construction phase of the three tiles, the equation 3.1 describes the total emissions of the building:

$$E\ total = \sum_{i=1}^{3} Ei \tag{3.1}$$

$E\ total$ It is the total energy of carbon dioxide emissions per kilogram equivalent to the amount of carbon dioxide during the construction stages.

Ei is the emission of CO_2 based on the system boundary for each stage of the buildings.

i is the calculation of the quantitative method for each stage from 1 to 3

$$E1 = \sum_{i=1}^{3} Mj\ X\ fj \tag{3.2}$$

In the equation 3.2 it describes the CO_2 emission of the whole materials of the building in Kilograms CO_2. Where Mj is the quantity of the materials of the buildings for both concrete and steel by using volume (m3) for calculation the amount of the concrete and with using the weight mass in kg for calculating the amount of the rebars, metal materials in the buildings, and m2 for decking material for the steel decking).

Fj factor is the factor of the carbon dioxide emissions of the buildings, which can be different from a region to another. Based on the United States life Cycle database NREL and its partners created the U.S. Life Cycle Inventory (USLCI) Database [18].

$$E2 = \sum_{k=1}^{3} X\ \sum_{k=10}^{j} Lc\ X\ Nt\ X\ ftrans \tag{3.3}$$

$E2$ describes the sum of CO_2 emissions from vehicle exhausts during the process of transporting materials to the construction site and is calculated in kilograms for each CO_2 emissions.

Lc is the amount of fuel consumed in liter units during transportation to the sit.

Nt is the number of vehicles needed to transport building materials to the site.

$ftrans$ is the carbon factor of the compounds and it differs from one vehicle to another in addition to the calculation of the distance between the supplier and the construction site. Therefore, the emission factor for dioxide differs from one country to another country.

$$E3 = \sum Fj \; x \; fj \tag{3.4}$$

It is the total carbon dioxide emissions resulting from energy consumption of construction equipment, and its unit is symbolized in kilograms equivalent to carbon dioxide emissions. Fj is the Fj is the amount of fuel, in liters, resulting from its consumption to operate construction equipment.

fj is the carbon dioxide emission factor for the fuel varies by the quality of the fuel and the amount consumed by the equipment.

CHAPTER 4

DESCRIPTION OF THE CASE STUDY

4.1 Introduction

In this chapter it illustrates the impact of concrete and steel buildings and industry concerning both to know their emission of energy for both buildings on the environment and to illustrate previous studies concerning our subject relating to the environmental impact. The conclusion will be based upon these previous studies and in this study. the investigates on the specific information that can be related to the environmental impact will be considered.

There are 16 different buildings type of buildings that were being analyzed and designed due the slab system (Solid Slab Buildings and Steel composite Slabs). Each type which mentioned is divided into two locations (General USA and CA). 4 Buildings as solid slabs stories. Those buildings were designed as 4 elevations (one story, two stories, Three stories, and four stories. Solid Slab buildings are under B category, where steel composite structure is under A category.

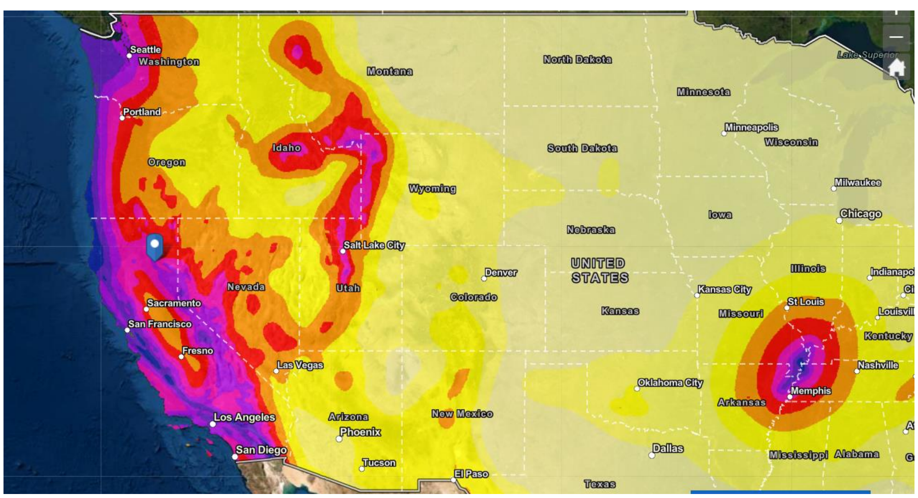


Figure 4.1: American Seismic Zoning Map [19]

Analysis of seismic is considered as a fundamental of structural analysis for buildings and non-other type structures. In areas which earthquakes occur, analyzing is a part of structural engineers, earthquake engineers. The seismic ground waves study is a part taken into consideration when analyzing the building. The analysis types are varied to study the response of seismic ground wave system.

Analysis Type	Linear	Nonlinear
Static	Strength-based	Static pushover
Dynamic	Response-spectrum	Time-history

Table 4.1: Approaches for Investigating Seismic Ground Wave System Responses [19]

4.2 Response Spectrum

The ground motion versus frequency technique is used to analyze spectrum. Seismic maps and soil properties are used to estimate the ultimate acceleration for a given frequency and damping. The larger acceleration, the lower the attenuation.

When the analysis is done, lateral forces, moments, shears, and displacements at each location is derived for each system's natural frequency. The square root total of the response squares in each of the three directions is commonly used to determine the estimated loads, displacements, and stresses of the structure system.

The dynamic analysis has been taken in this study as a linear part for the buildings been considered in USA, the data has been collected from ASCE7-16 standard as it refers for ZA soil class (hard rock). All structures were studied under the same conditions.

Soil Type	ASCE7-16 - Definition
ZA	Hard rock
ZB	Rock
ZC	Very dense and soft rock
ZD	Stiff soil
ZE	Soft clay soil
ZF	Soils requiring response analysis

Table 4.2: Ground Types [20].

Fs	Ss ≤0.25	Ss ≤0.5	Ss ≤0.75	Ss ≤1	Ss ≤1.25	Ss ≤1.5
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.9	0.9	0.9	0.9	0.9	0.9
ZC	1.3	1.3	1.2	1.2	1.2	1.2
ZD	1.6	1.4	1.2	1.1	1	1
ZE	2.4	1.7	1.3			

Table 4.3: Short Period Site Coefficient Fa [20].

Fv	S1 ≤0.1	S1 ≤0.2	S1≤0.3	S1 ≤0.4	S1 ≤0.5	S1 ≤0.6
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.8	0.8	0.8	0.8	0.8	0.8
ZC	1.5	1.5	1.5	1.5	1.5	1.4
ZD	2.4	2.2	2	1.9	1.8	1.7
ZE	4.2					

Table 4.4: Long Period Site Coefficient Fv [20].

The study took place in California as figure (4.2)

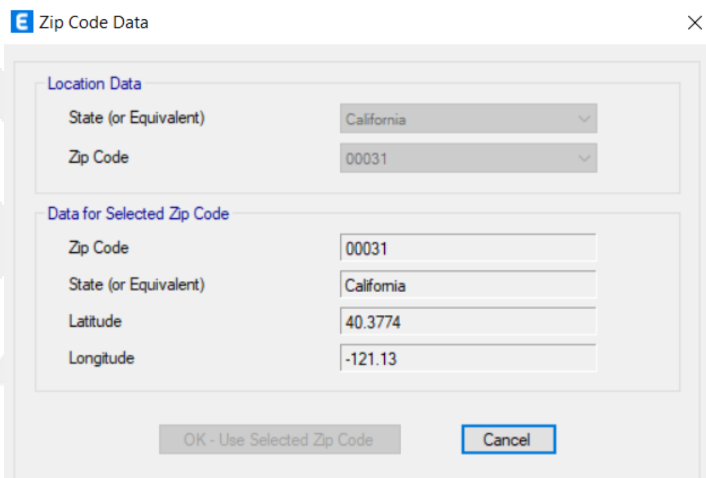


Figure 4.2: Location of the Buildings-ETABS V19

Sa and S1 is taken from the seismic map or by inputting the site latitude and longitude in the ETABS V19 seismic loading in order to obtain the results needed.

$$S_{ae}(T) = \left(0.4 + 0.6\frac{T}{T_A}\right)S_{DS} \qquad (0 \leq T \leq T_A)$$

$$S_{ae}(T) = S_{DS} \qquad (T_A \leq T \leq T_B)$$

$$S_{ae}(T) = \frac{S_{D1}}{T} \qquad (T_B \leq T \leq T_L)$$

$$S_{ae}(T) = \frac{S_{D1}T_L}{T^2} \qquad (T_L \leq T)$$

Table 4.5: Spectral Acceleration Parameters Designing [20].

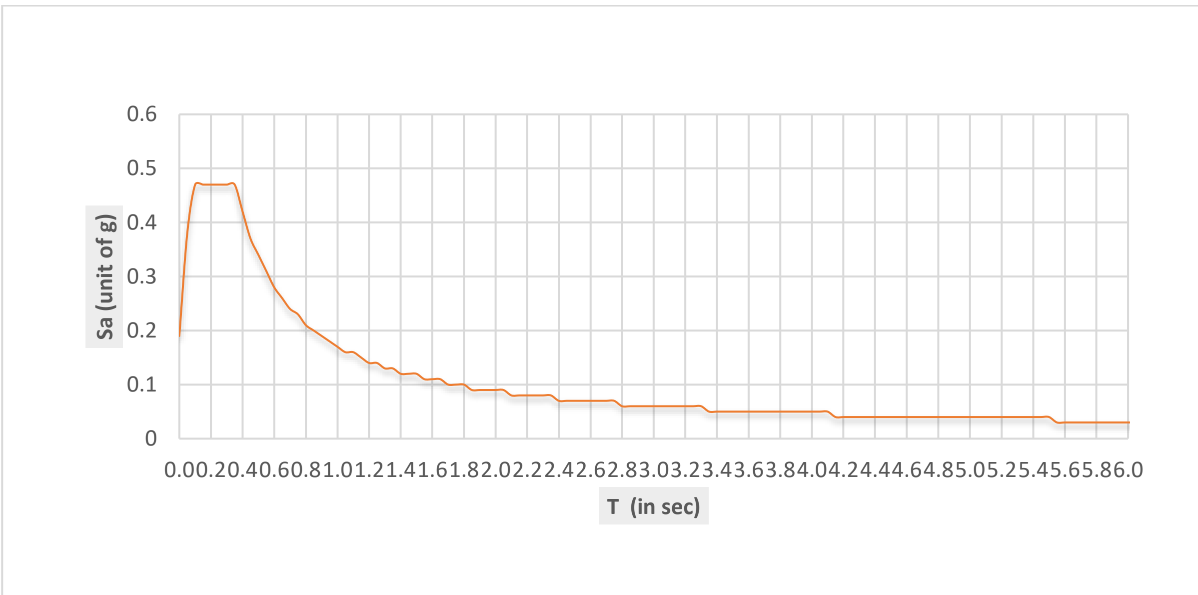


Figure 4.3: Period /Acceleration Graph

for (0≤T≤T0): $Sd = 0.8 * (0.4 + 0.6\ T/0.072)$ (4.1)

for (T0 ≤T≤TS): $Sd = 0.8$

for (TS ≤T≤TL): $Sd = (0.8/T)$

for (TL ≤T): $Sd = (0.8*6/T\string^2)$

TL= 6 sec R= 8 Ie= 1.25

Site Class	A
0.2 Sec spectrum Acceleration, Sa	0.8646
1 Sec spectrum Acceleration, S1	0.3096
Site coefficient, Fa	0.8
Site coefficient, Fv	0.8
Calculated Value for response Curve	
SDS = (2/3) *Fa*Sa	0.4611
SD1 = (2/3) *Fv*S1	0.1651

Table 4.6: Response Spectrum Calculation

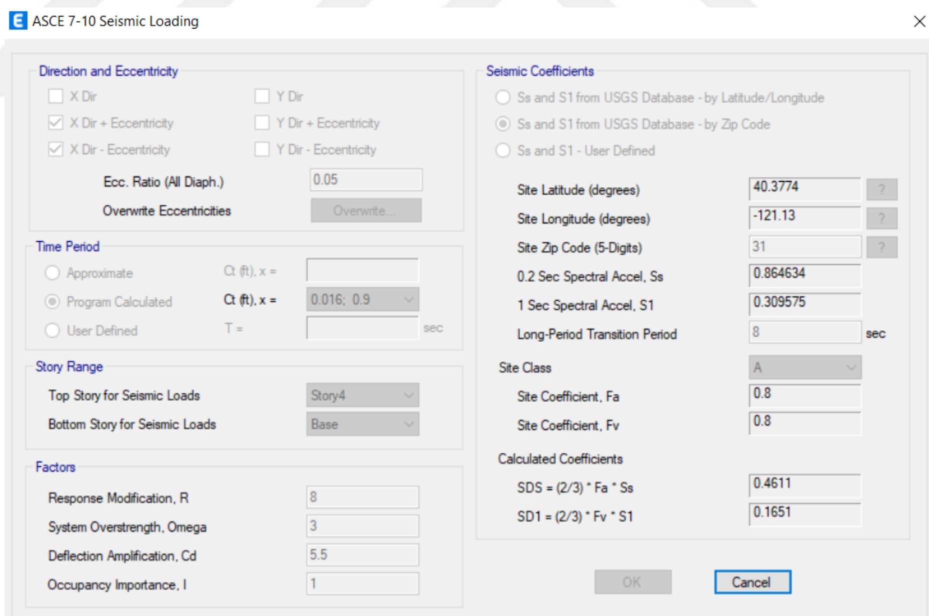


Figure 4.4: Seismic Calculations

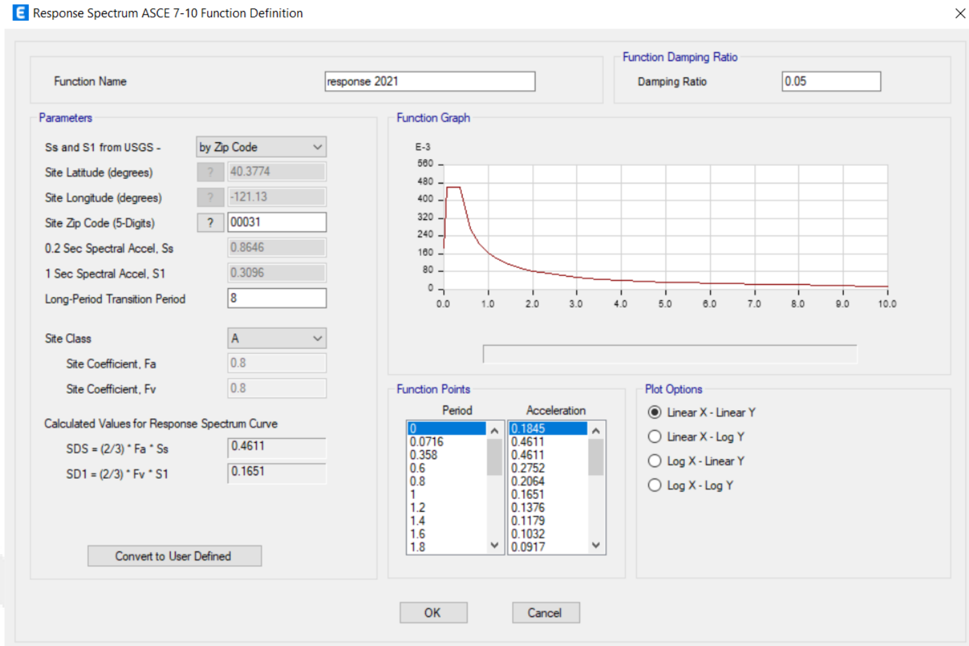


Figure 4.5: ETABS Spectrum Response

The damping ratio for the buildings is sat to 0.05. While the long period is sat to 8. As it is input it manually into the function definition in ETABS.

4.2 Site Specific Design Requirement

The combinations which have been used for modeling and designing are written in the table 4.7 The DL for the slabs of the buildings is 2 KN/m^2 , for the LL is 2 KN/m^2 and the LL of the roof is taken as 1 KN/m^2

CONCRETE STRUCTURE
1.4 DL
1.2 DL + 1.6 LL
1.3 DL + 1 LL + 1 EX
1.3 DL + 1 LL + 1 EY
0.8 DL + 1 EX
0.8 DL + 1 EY
COMPOSITE SLAB
1.5DL
DL
DL+LL
1.35DL
1.35DL+1.5LL
STEEL STRUCTURE
1.4 DL+1.6LL
1.35DL
1.35DL+1.5LL
DL+1.3LL+EX
DL+1.3LL+EY
DL+EX
DL+EY

Table 4.7: Load Combinations [20]

4.3 Building Designs

4.3.1 Reinforced Concrete Structural Design.

The concrete Grade is C25, Rebars Material: S40

Floor number: 1,2,3,4 story buildings

Floor's height: 3 m

Soil Type: ZA

Building type: n=0.3

Dead load (plastering + covering), DL = 2 KN/m^2

Live Load (Slab & Staircase), LL = 2 KN/m^2

Live Load for the roofs (Slab & Staircase), LL = 1 KN/m^2

The ETABS software is used for analyzing the buildings, all the following procedures are shown in figures bellow.

- Selecting a new modal

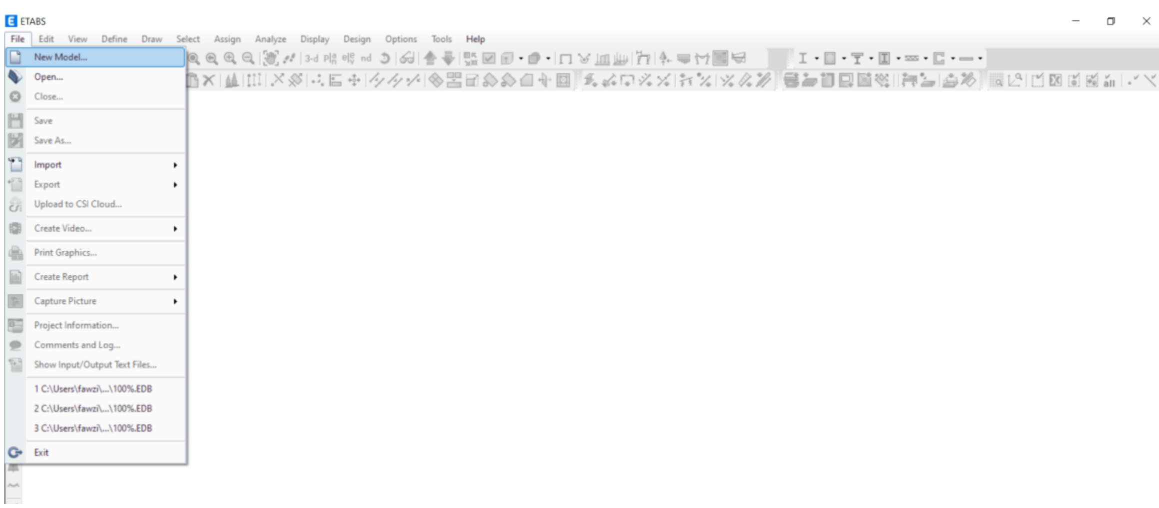


Figure 4.6: Home Page of ETABS

- Choosing the design code with unites display as SI matric and ACI. The seismic analysis is analyzed due to AISC14 16.

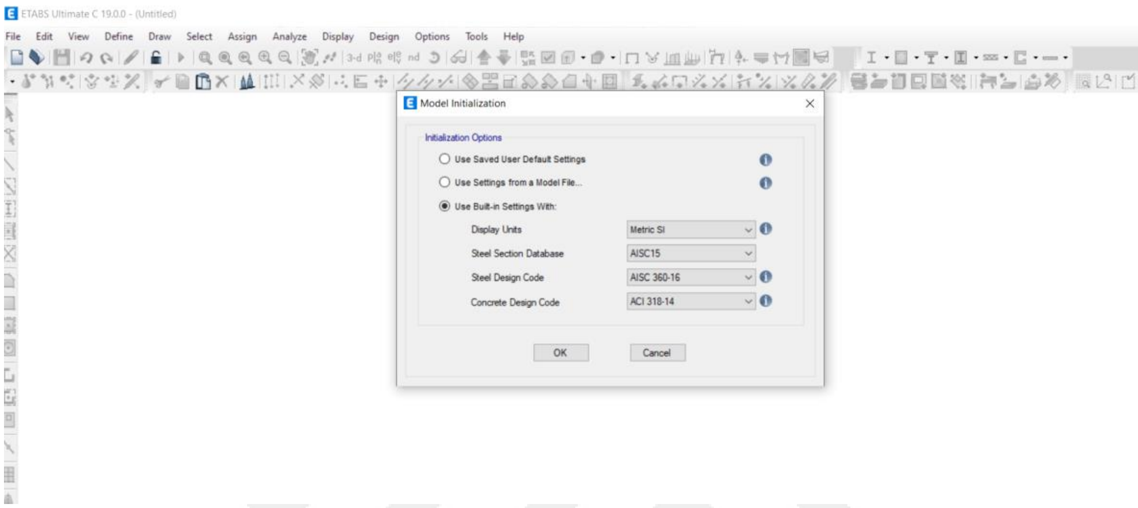


Figure 4.7: Selecting the Codes

- The Following procedure is to set the grids map, and by modifying the grids in X and Y axis.

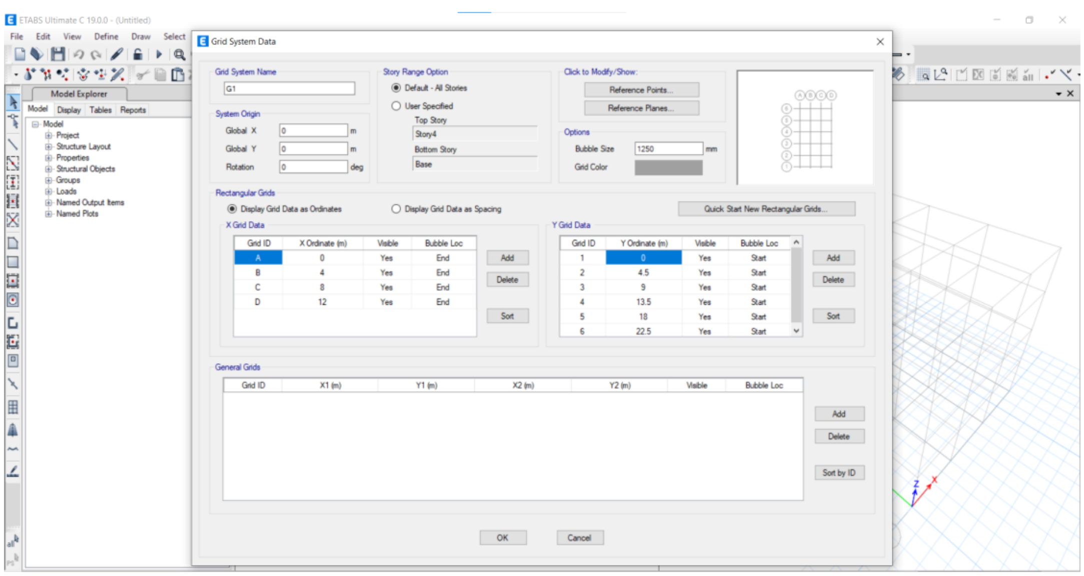


Figure 4.8: Structure Grids

- The material properties are selected in our sections.

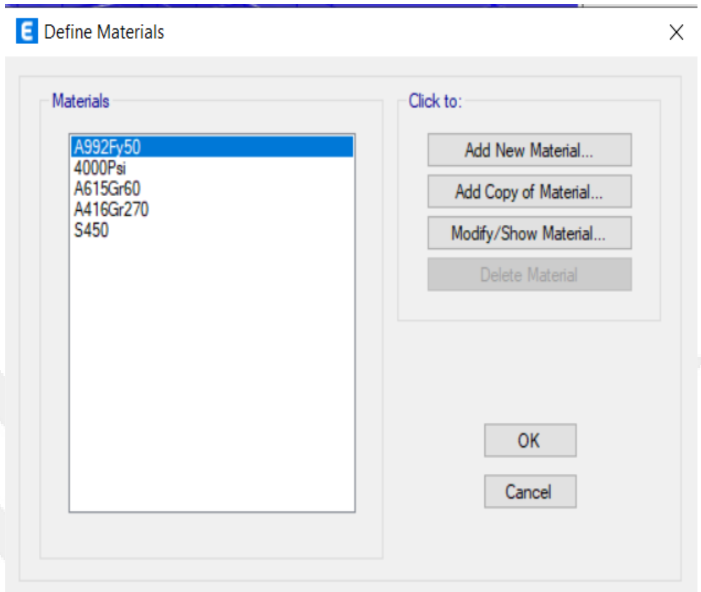


Figure 4.9: Defining the Materials

- Carry out automated design and ensure that the portions provided are adequate. If this isn't the case, rearrange the parts such that all of the frame elements are present. Only the longitudinal reinforcing regions of beams and columns need to be designed.

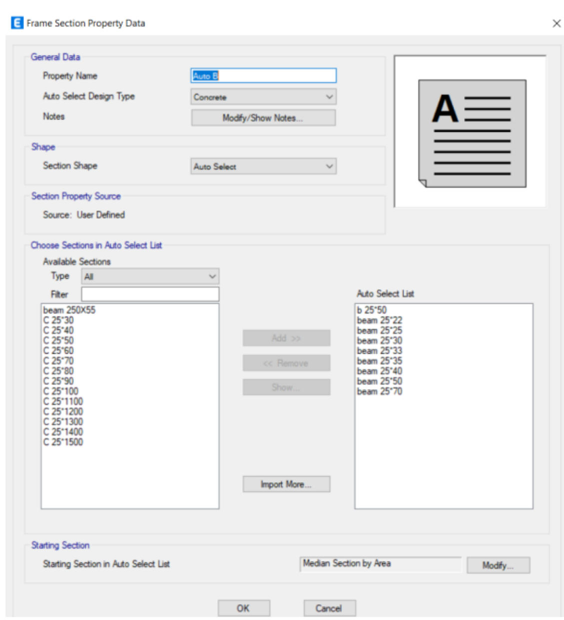


Figure 4.10: Beams Section Property

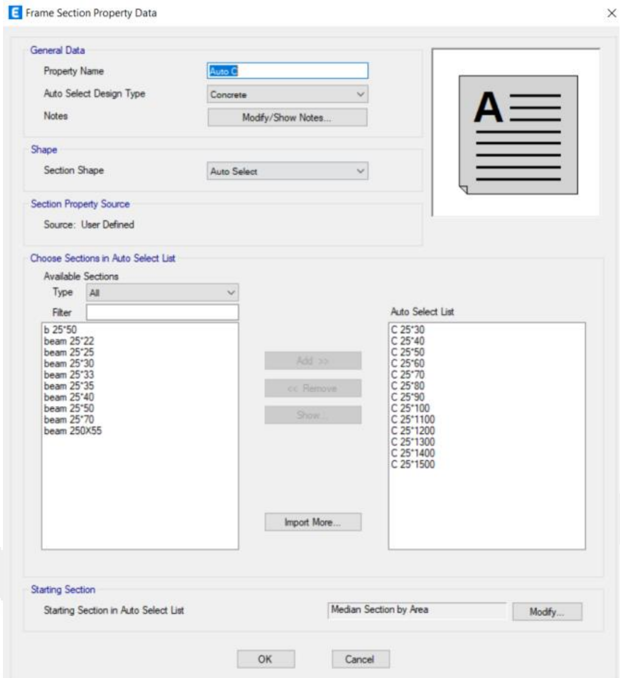


Figure 4.11: Columns Section Property

- Select the concrete grade and rebar type, as well as the items (beams, columns, slabs).

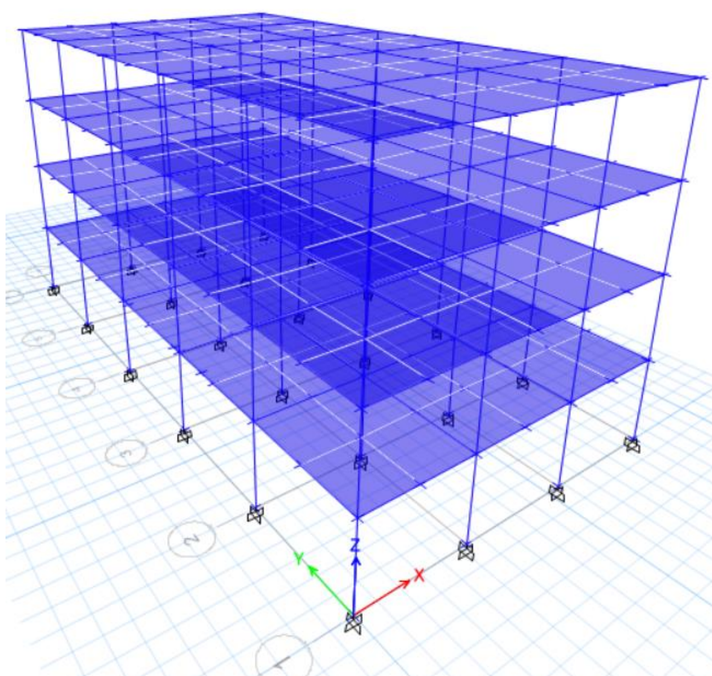


Figure 4.12: 3D Models in ETABS

* Defining the load pattern and set the mass source factor of LL to 0.3

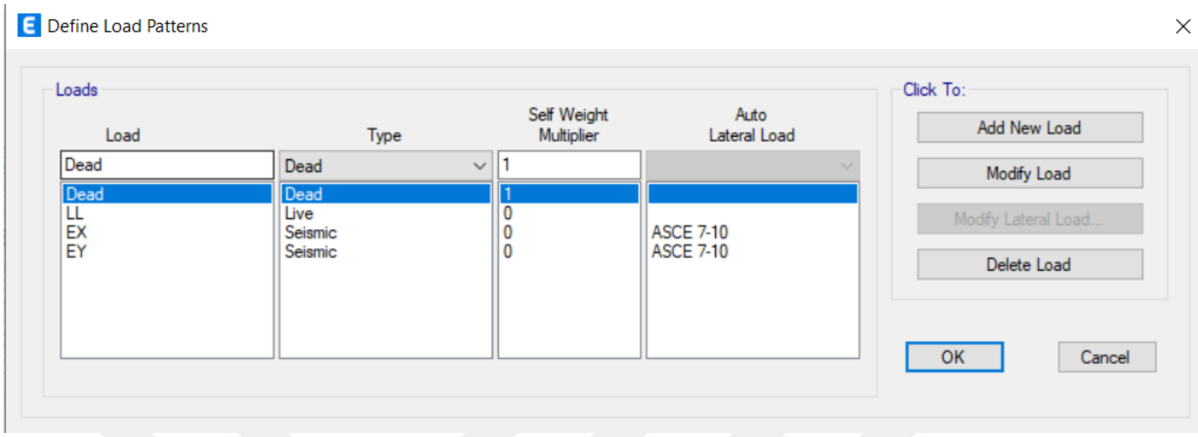


Figure 4.13: Define Load Pattern

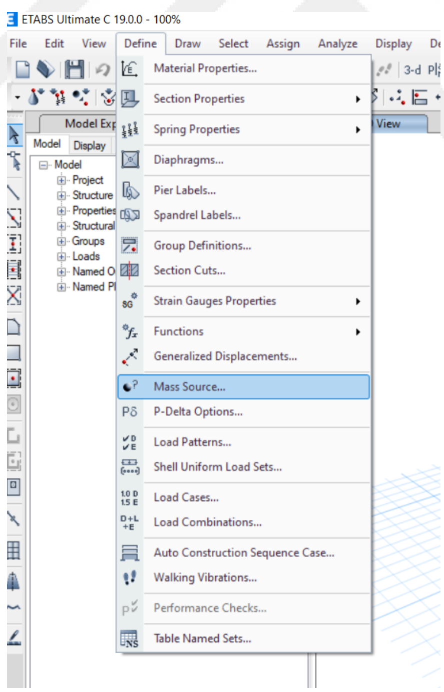


Figure 4.14: Mass Source Icon

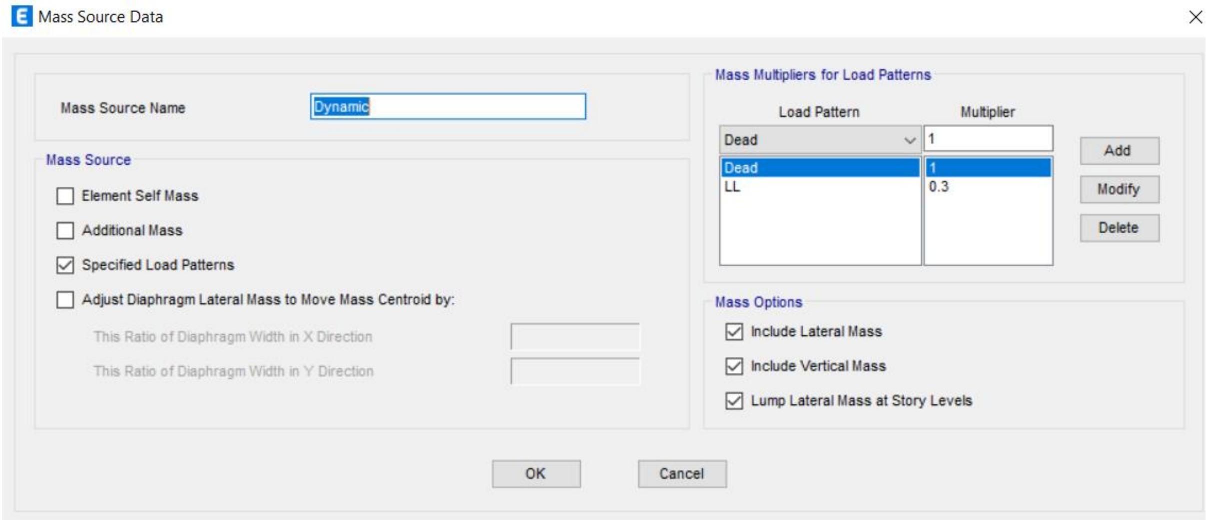


Figure 4.15: Mass Source Data

- In our analysis, response spectrum has been considered. Thus, it should be defined in the load case data section.

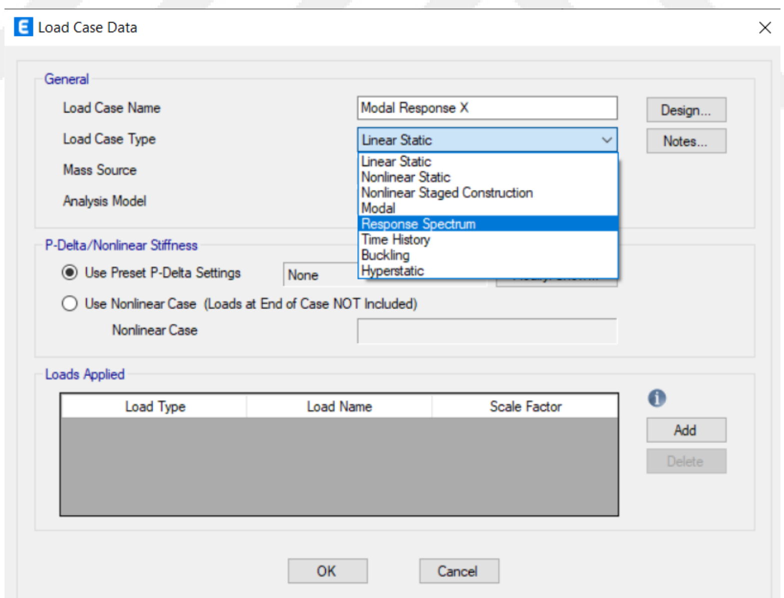


Figure 4.16: Load Case Data

- The modal load case for the response spectrum x and y is SRSS whilst the directional combination type is sat to SRSS.

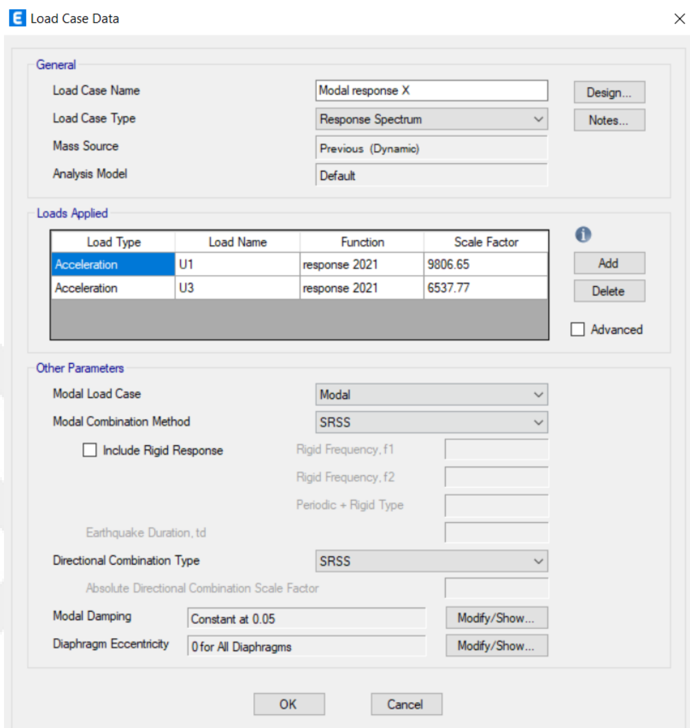


Figure 4.17: Load Case Data2

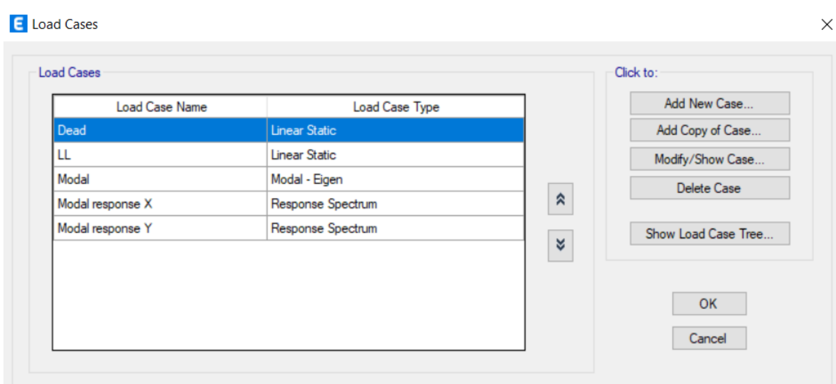


Figure 4.18: Load Cases for the Modals

- The project is ready to analysis. By clicking on the run icon. The buildings start modeling and results come out.

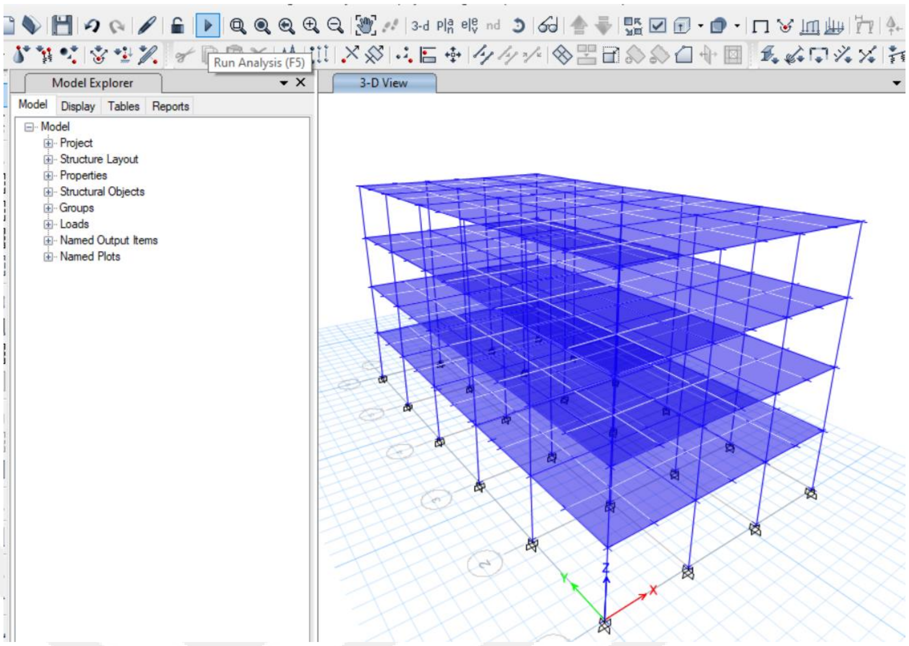


Figure 4.19: Entire modal of the ETABS

- After obtaining the displacement results, the result should follow the requirement for ACI standard.

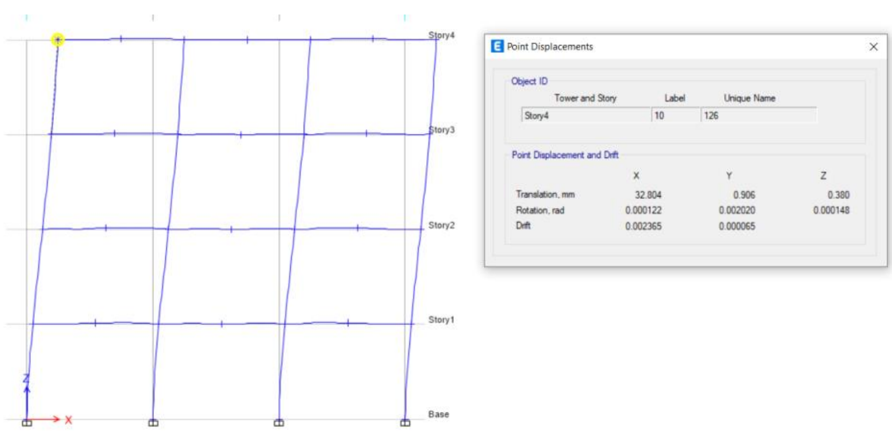


Figure 4.20: Displacement of the Frame

- In obtain the steel area for both columns and beams. We click on design and check icon.

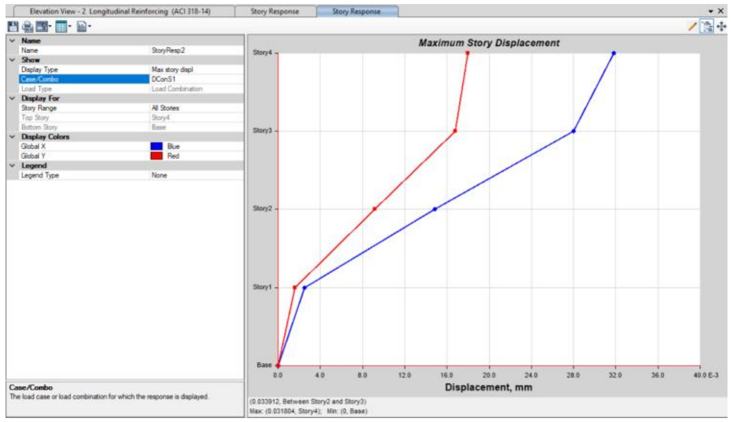


Figure 4.21: Maximum Story Displacement DConS1

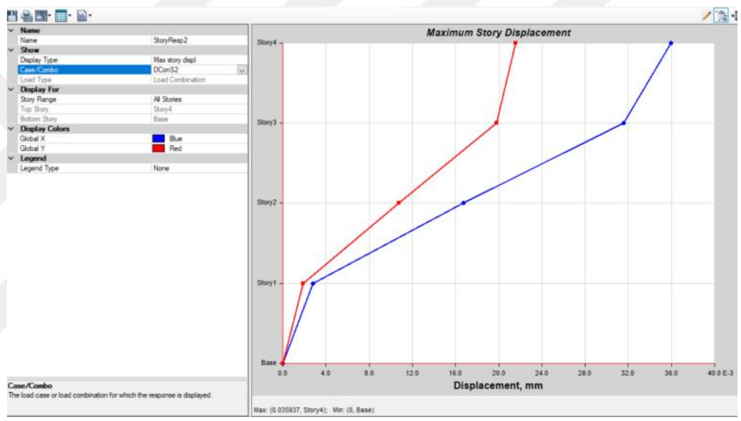


Figure 4.22: Maximum Story Displacement DConS2

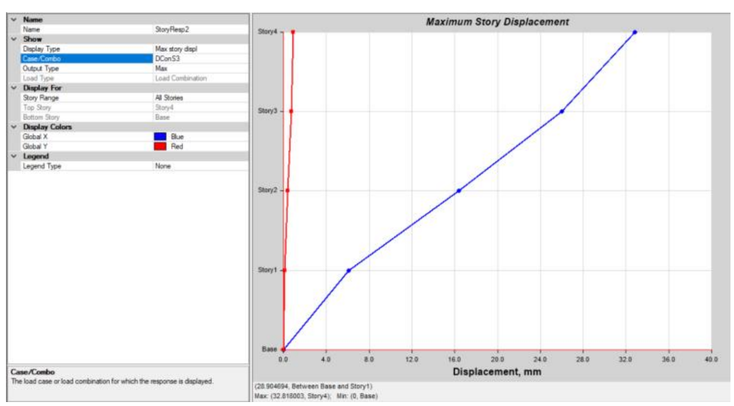


Figure 4.23: Maximum Story Displacement DConS3

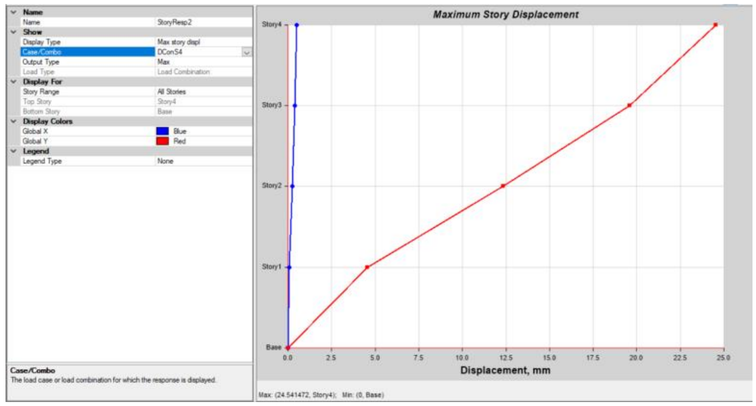


Figure 4.24: Maximum Story Displacement DConS4

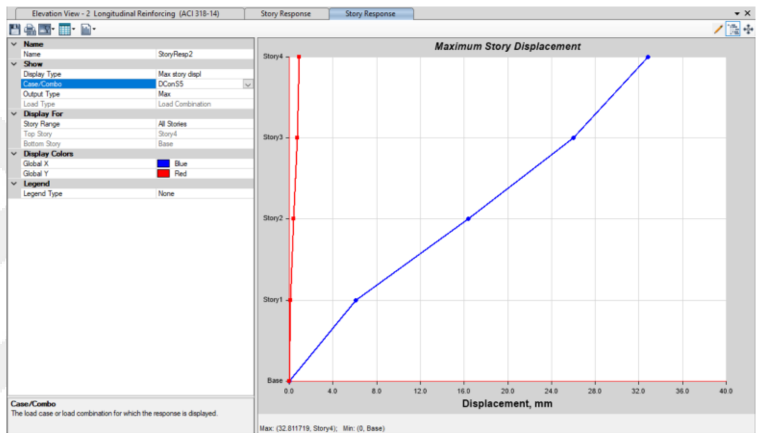


Figure 4.25: Maximum Story Displacement DConS5

Figure 4.26: Maximum Story Displacement DConS6

Story	diaphragm	m_x	m_y	Mass center		Stiffness Center	
				x_m	y_m	x_r	y_r
Story1	D1	150869.85	150869.85	6.00	11.25	6.00	11.23
Story2	D2	124458.85	124458.85	6.00	11.25	5.99	11.13
Story3	D3	123738.02	123738.02	6.00	11.25	5.98	11.04
Story4	D4	103955.67	103955.67	6.01	11.21	5.99	11.04

Eccentricity		Length of the building		ex/Dx	ey/Dy
e_x= xm - xr	e_y=ym-yr	Dx	Dy	%	%
0.00	0.02	22.5	12	**0.0**	**0.1**
0.01	0.12	22.5	12	**0.0**	**1.0**
0.02	0.21	22.5	12	**0.1**	**1.8**
0.02	0.17	22.5	12	**0.1**	**1.4**

Table 4.8: Eccentricity Check.

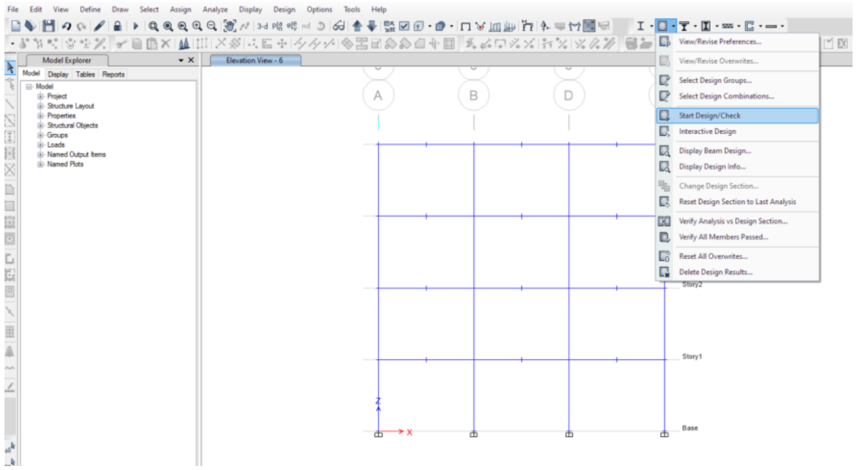


Figure 4.27: Starting the Design Procedure

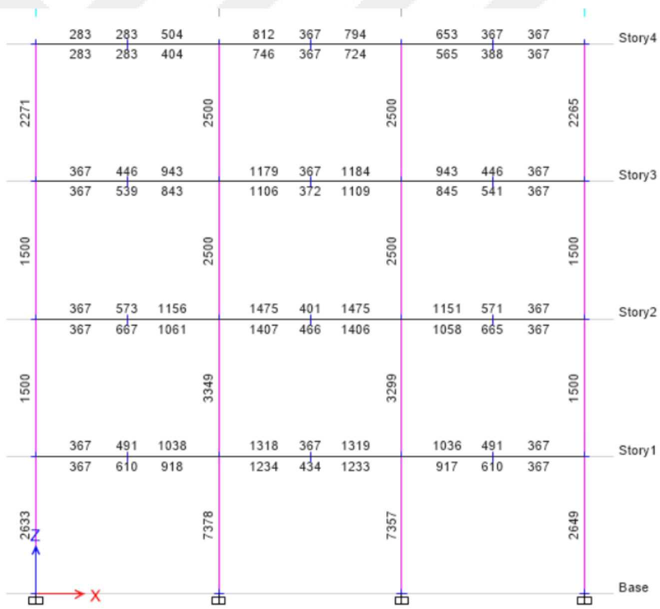
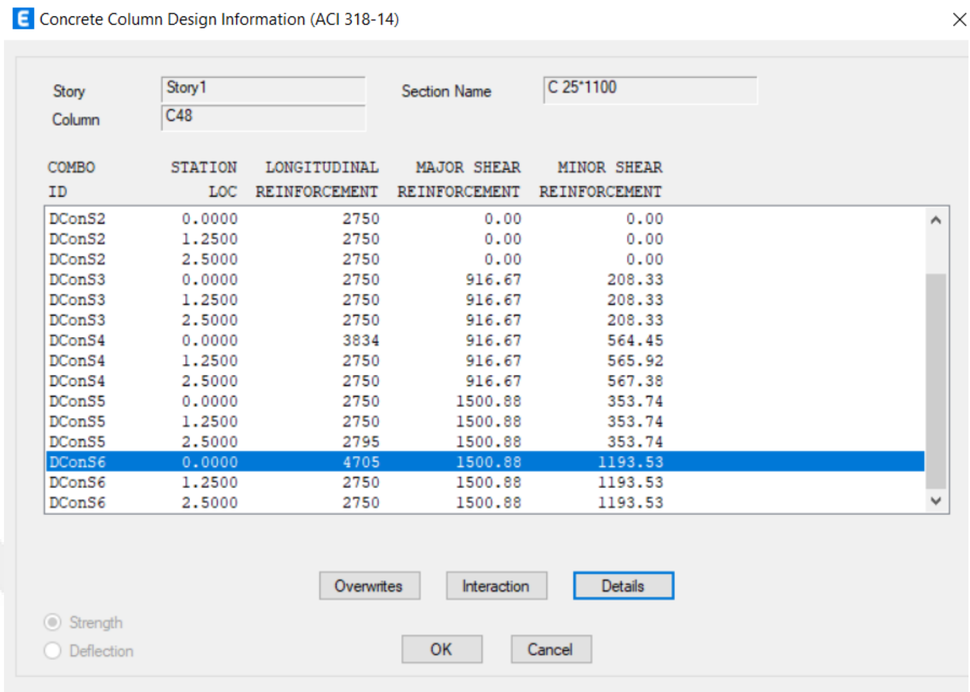


Figure 4.28: Steel Area for the Columns and Beams.

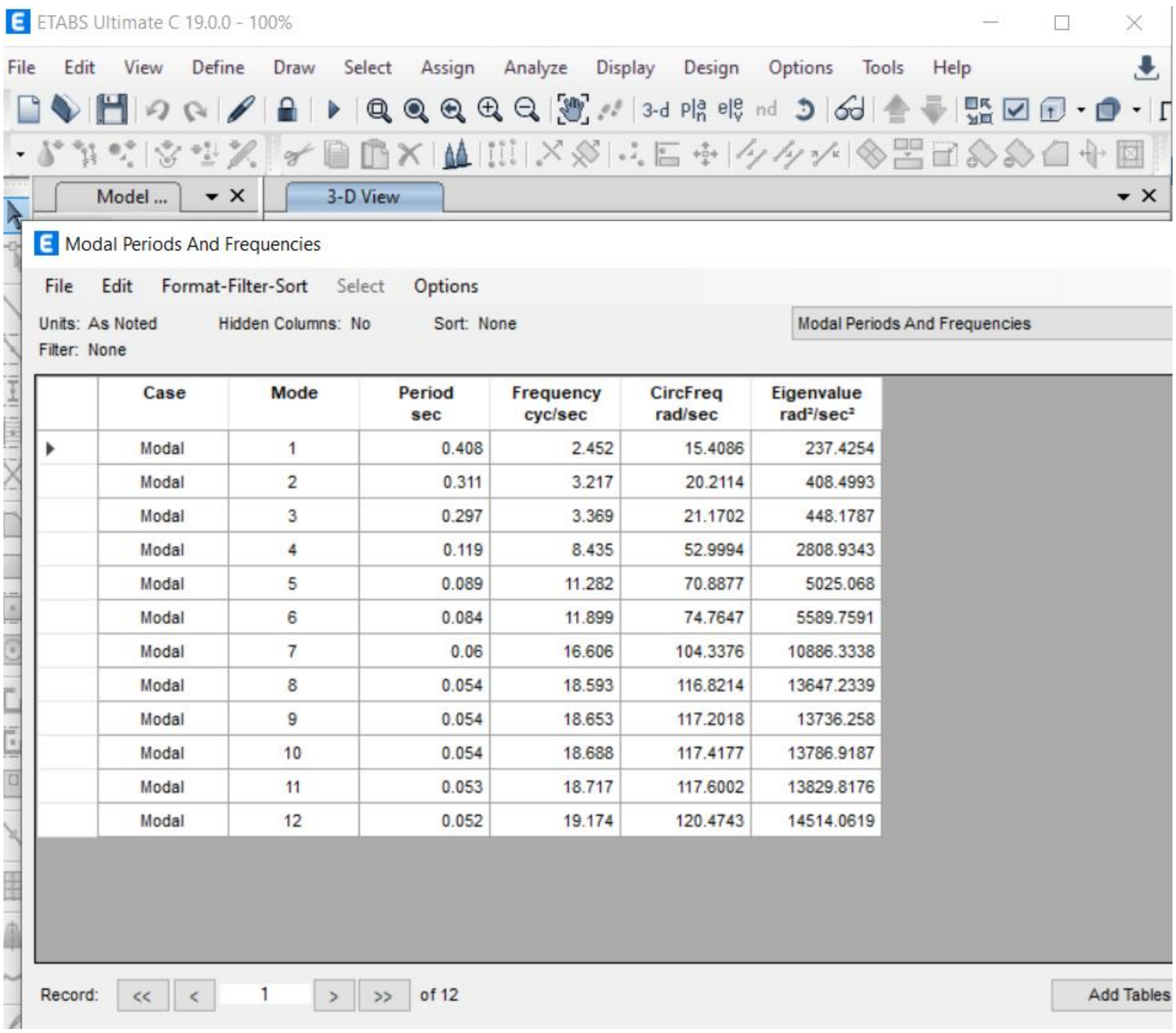


COMBO ID	STATION LOC	LONGITUDINAL REINFORCEMENT	MAJOR SHEAR REINFORCEMENT	MINOR SHEAR REINFORCEMENT
DConS2	0.0000	2750	0.00	0.00
DConS2	1.2500	2750	0.00	0.00
DConS2	2.5000	2750	0.00	0.00
DConS3	0.0000	2750	916.67	208.33
DConS3	1.2500	2750	916.67	208.33
DConS3	2.5000	2750	916.67	208.33
DConS4	0.0000	3834	916.67	564.45
DConS4	1.2500	2750	916.67	565.92
DConS4	2.5000	2750	916.67	567.38
DConS5	0.0000	2750	1500.88	353.74
DConS5	1.2500	2750	1500.88	353.74
DConS5	2.5000	2795	1500.88	353.74
DConS6	0.0000	4705	1500.88	1193.53
DConS6	1.2500	2750	1500.88	1193.53
DConS6	2.5000	2750	1500.88	1193.53

Figure 4.29: Longitudinal Steal Area of the Columns.

Inputs data:

k1 =175820.546 KN/m;
k2 = 242900.941 KN/m.
k3 = 460140.993 KN/m.
m1 = 150.71968 TON.
m2 = 124.39878 TON.
m3 = 103.95567 TON.



Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad²/sec²
Modal	1	0.408	2.452	15.4086	237.4254
Modal	2	0.311	3.217	20.2114	408.4993
Modal	3	0.297	3.369	21.1702	448.1787
Modal	4	0.119	8.435	52.9994	2808.9343
Modal	5	0.089	11.282	70.8877	5025.068
Modal	6	0.084	11.899	74.7647	5589.7591
Modal	7	0.06	16.606	104.3376	10886.3338
Modal	8	0.054	18.593	116.8214	13647.2339
Modal	9	0.054	18.653	117.2018	13736.258
Modal	10	0.054	18.688	117.4177	13786.9187
Modal	11	0.053	18.717	117.6002	13829.8176
Modal	12	0.052	19.174	120.4743	14514.0619

Figure 4.30: Modal Periods and Frequencies.

By applying SRSS method in order to get the modes shapes, eigenvalues and the periods of the structures we have. The ETABS generates the table in the figure 4.30 by showing the period, frequency, and Eigenvalue. For period 0.408 sec the eigenvalue is determined as 237.425 rad^2/sec^2. While the period of the second modal is 0.311 sec while the eigenvalue of it is 408.499 rad^2/sec^2.

By doing interpolation for getting the eigenvalue of the period1 which is 0.0648 sec.

$$y = y1 + (x - x1)\frac{(y2-y1)}{(x2-x1)} \quad (4.2)$$

Y= linear interpolation value

X = independent variable

X1,y1= values of the functions at one point

X2,y2= values of the functions at another point.

Period	Eigenvalue from the code	Eigenvalue from ETABS
0.338	345.64	360.88
0.1129	3100	3259.546287
0.0648	9410	9827.01886

Table 4.9: Comparing Eigenvalues and Periods.

As the table 4.9 shown, it’s pretty clear that the code has meet almost the same results as the ETABS has. Since the building is consisting of three stories, it generates the multi degree of freedoms, each parts generates a modal in respect of the height, that’s why the matrixes are needed.

F= ΓI*Sai*m*Ø (4.3)

Γ: modal contribution factor

Sa: Ground motion acceleration.

M: mass

Ø: mode shape

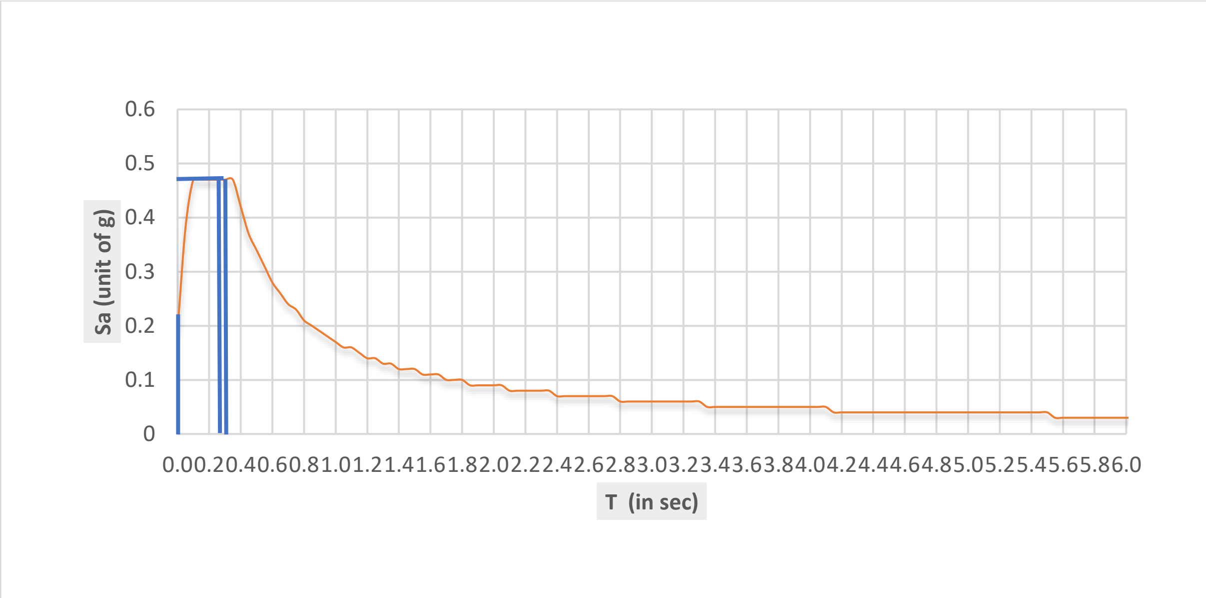


Figure 4.31: Design Response Spectrum.

Period1 =	Modal1_contribution_factor =	Mode1 =	m1	sa	F= ΓI*Sai*m*Ø
0.0648	-0.0211	-0.243	150.71968	0.22	1.66782462
0.0648	-0.0211	1	150.71968	0.22	-6.863475802
0.0648	-0.0211	-0.888	150.71968	0.22	6.094766512
				Vb1	0.89911533
Period2 =	Modal2_contribution_factor =	Mode2 =	m2		
0.1129	-0.2812	-1	124.39878	0.48	164.7182358
0.1129	-0.2812	0.1995	124.39878	0.48	-32.86128805
0.1129	-0.2812	0.6655	124.39878	0.48	-109.619986
				Vb23	22.23696184
Period3 =	Modal3_contribution_factor =	Mode3	m3		
0.338	-1.1684	-0.6108	103.95567	0.46	334.7846965
0.338	-1.1684	-0.9219	103.95567	0.46	505.3012635
0.338	-1.1684	-1	103.95567	0.46	548.1085405
				Vb3	1388.1945

Table 4.10: Base Shear Calculations.

$$\text{SRSS} = \sqrt{vb1^2 + vb2^2 + vb3^2} \qquad (4.4)$$

$$= \sqrt{0.899^2 + 22.2^2 + 1388.19^2} = 1388.373 \text{ KN}$$

Eigen value modal method software coding for 3 story buildings

```
k1 =175820.546 ;
k2 = 242900.941;
k3 = 460140.993;
m1 = 150.71968;
m2 = 124.39878;
m3 = 103.95567;
Mmat = [m1 0 0;0 m2 0; 0 0 m3]
Kmat = [(k1+k2) -k2 0;-k2 (k2+k3) -k3;0 -k3 (k3)]
```

```
A = Kmat/Mmat;
%Calculate eigenvalues and eigenvectors of A
[V,D] = eig(A);
[V,D] = eig(sym(A));
det(A-D(1,1)*eye(3))
[V,D] = eig(sym(A));
det(A-D(2,2)*eye(3))
[V,D] = eig(sym(A));
det(A-D(3,3)*eye(3))

[eig_vector,eig_value]=eig(A)

B1=eig_value(1)*[1;1;1]
B2=eig_value(5)*[1;1;1]
B3=eig_value(9)*[1;1;1]

C3= [B3(1) 0 0;0 B3(2) 0;0 0 B3(3)]
D3=Kmat-C3*Mmat
Mode3= D3^-1*[0 ;0;1]
Mode3=Mode3/(max(abs(Mode3)))
C2= [B2(1) 0 0;0 B2(2) 0;0 0 B2(3)]
D2=Kmat-C2*Mmat
Mode2= D2^-1*[0 ;0;1]
Mode2=Mode2/(max(abs(Mode2)))
C1= [B1(1) 0 0 ;0 B1(2) 0 ;0 0 B1(3)]
D1=Kmat-C1*Mmat
Mode1=  D1^-1*[0 ;0;1]
Mode1=Mode1/(max(abs(Mode1)))

Mode1
Mode2
Mode3

eigenvalueW1 = eig_value(1)
eigenvalueW2=eig_value(5)
eigenvalueW3=eig_value(9)

Period1=2*pi/ eigenvalueW1^0.5
Period2=2*pi/ eigenvalueW2^0.5
Period3=2*pi/ eigenvalueW3^0.5

[Period1 Period2 Period3]

Modal_Matrix=[Mode1 Mode2 Mode3]

Modal_mass=Modal_Matrix.'*Mmat*Modal_Matrix
```

```
M1= Modal_mass(1)
M2= Modal_mass(5)

L1= transpose(Mode1)*Mmat*[1;1;1]
L2= transpose(Mode2)*Mmat*[1;1;1]
L3= transpose(Mode3)*Mmat*[1;1;1]

Modal1_contribution_factor =((transpose(Mode1))*Mmat*[1;1;1])/Modal_mass(1)
Modal2_contribution_factor =((transpose(Mode2))*Mmat*[1;1;1])/Modal_mass(5)
Modal3_contribution_factor =((transpose(Mode3))*Mmat*[1;1;1])/Modal_mass(9)

Effective_Modal1 =(((transpose(Mode1))*Mmat*[1;1;1])*
((transpose(Mode1))*Mmat*[1;1;1])/Modal_mass(1))
Effective_Modal2=(((transpose(Mode2))*Mmat*[1;1;1])*
((transpose(Mode2))*Mmat*[1;1;1])/Modal_mass(5))

Effective_Modal3 =(((transpose(Mode3))*Mmat*[1;1;1])*
((transpose(Mode3))*Mmat*[1;1;1])/Modal_mass(9))

Effective_Modal3+ Effective_Modal2+ Effective_Modal1
Sum_mass=Mmat(1)+Mmat(5)+Mmat(9)

mass_contibution_factor=M1*Modal1_contribution_factor*Modal1_contribution_factor/Sum_mass
mass_contibution_factor=M2*Modal2_contribution_factor*Modal2_contribution_factor/Sum_mass
mass_contibution_factor=M3*Modal3_contribution_factor*Modal3_contribution_factor/Sum_mass



Mmat =
  150.7197         0         0
         0  124.3988         0
         0         0  103.9557

Kmat =
   1.0e+05 *
    4.1872   -2.4290         0
   -2.4290    7.0304   -4.6014
         0   -4.6014    4.6014

eig_vector =
   -0.2301   -0.8988    0.5112
    0.7815    0.1480    0.6368
   -0.5799    0.4126    0.5772

eig_value =
   1.0e+03 *
    9.4107         0         0
         0    3.0996         0
         0         0    0.3456
```

```
B1 =
   1.0e+03 *
    9.4107
    9.4107
    9.4107
B2 =
   1.0e+03 *
    3.0996
    3.0996
    3.0996


B3 =
  345.6403
  345.6403
  345.6403

C3 =
  345.6403         0         0
         0  345.6403         0
         0         0  345.6403

D3 =
   1.0e+05 *
    3.6663   -2.4290         0
   -2.4290    6.6004   -4.6014
         0   -4.6014    4.2421

Mode3 =
   1.0e+10 *
   -4.9636
   -7.4918
   -8.1264

Mode3 =
   -0.6108
   -0.9219
   -1.0000

C2 =
   1.0e+03 *
    3.0996         0         0
         0    3.0996         0
         0         0    3.0996

D2 =
   1.0e+05 *
   -0.4845   -2.4290         0
   -2.4290    3.1745   -4.6014
         0   -4.6014    1.3792
```

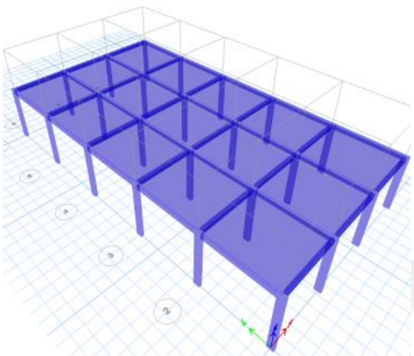
```
Mode2 =
   1.0e+09 *
   -1.3742
    0.2741
    0.9145

Mode2 =
   -1.0000
    0.1995
    0.6655

C1 =
   1.0e+03 *
    9.4107         0         0
         0    9.4107         0
         0         0    9.4107
D1 =

   1.0e+05 *

   -9.9966   -2.4290         0
   -2.4290   -4.6764   -4.6014
         0   -4.6014   -5.1816
Mode1 =

   1.0e+08 *

   -1.9914
    8.1955
   -7.2778


Mode1 =
   -0.2430
    1.0000
   -0.8880


Mode2 =
   -1.0000
    0.1995
    0.6655

Mode3 =
   -0.6108
   -0.9219
   -1.0000

eigenvalueW1 =   9.4107e+03
eigenvalueW2 =   3.0996e+03
```

```
eigenvalueW3 =  345.6403

Period1 =    0.0648
Period2 =    0.1129
Period3 =    0.3380

ans =
    0.0648    0.1129    0.3380




Modal_Matrix =
   -0.2430   -1.0000   -0.6108
    1.0000    0.1995   -0.9219
   -0.8880    0.6655   -1.0000

Modal_mass =
  215.2771   -0.0000    0.0000
   -0.0000  201.7102    0.0000
    0.0000    0.0000  265.9139


M1 =  215.2771
M2 =  201.7102
L1 =   -4.5397
L2 =  -56.7233
L3 = -310.6991

Modal1_contribution_factor =   -0.0211
Modal2_contribution_factor =   -0.2812
Modal3_contribution_factor =   -1.1684


Effective_Modal1 =    0.0957
Effective_Modal2 =   15.9513
Effective_Modal3 =  363.0271

ans =  379.0741

Sum_mass =  379.0741

mass_contibution_factor =   2.5254e-04
mass_contibution_factor =    0.0421
mass_contibution_factor =    0.9577
```

A	
12mWx22.5Ml	
Office Building	
USA standard	
Solid Slab Structure	
Number of stories: 1	Number of stories: 2
Total Height: 3	Total Height: 6
Thickness of slab: 18cm	Thickness of slab: 18cm
Interior Columns: 12	Interior Columns: 12
Total Columns: 24	Total Columns: 24
Roof Covering: Concrete	Roof Covering: Concrete
Number of stories: 3	Number of stories: 4
Total Height: 9	Total Height: 12
Primary Spacing between frames (BAY): 4.5m Y and 4m X	Primary Spacing between frames (BAY): 4.5m Y and 4m X
Roof Slop: 0	Roof Slop: 0
Interior Columns: 12	Interior Columns: 12
Total Columns: 24	Total Columns: 24

Table 4.11: Solid Structure Design

Solid Slabs



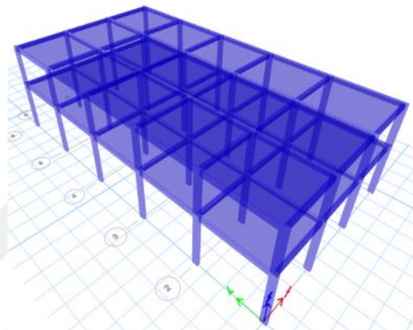


Figure 4.33: S1B2 (6m)

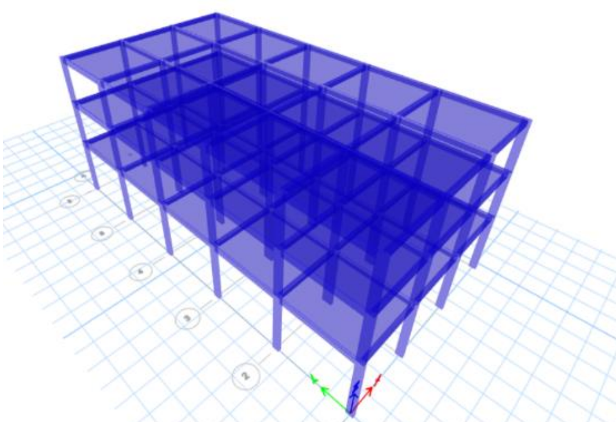


Figure 4.34: S1B3 (9m)

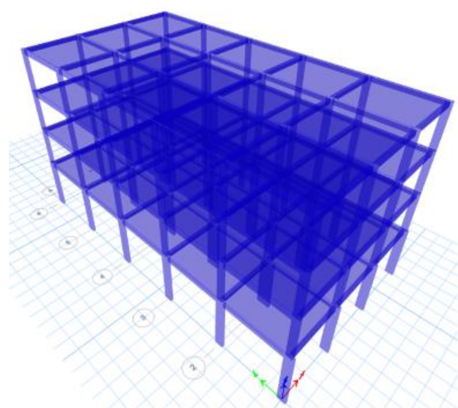


Figure 4.35: S2B4 (12m)

B: Indicates the number of buildings

S: the story number

Ex. B1S1 indicates building 1 the first story.

The layout for both solid slabs are identical due to the shorts span. Since the metal buildings can sustain longer spans, therefore the bays of steel buildings have increased.

Category Study	Bay in X	Bay in Y
A	4	4.5

Table 1.12: Solid Structure Dimension

The concrete structure contains a set of various columns, beams, Dropped beams, and simple footings. The layout of the concrete structure is similar between solid slabs. but, since the steel structure can sustain and hold longer spans, Therefore, the distance of the space increased in steel structure but remain the same in concrete buildings. Using the EIE program to model concrete slabs by adding the slab assemblies, it was found that the software assumes the span of the slab in two-way directions. Therefore, the amount of material has been added manually to the software.

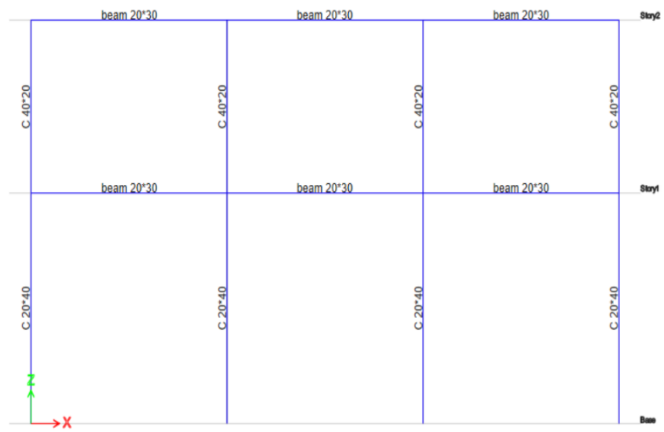


Figure 4.36: Concrete Building 1.

Figure 4.37: Concrete Building 2.

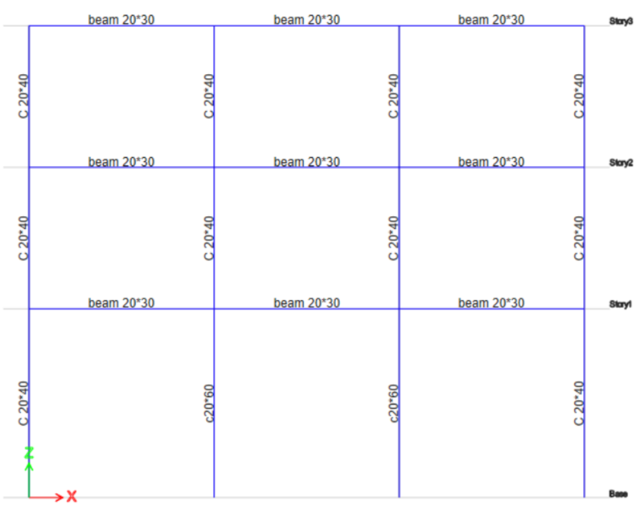
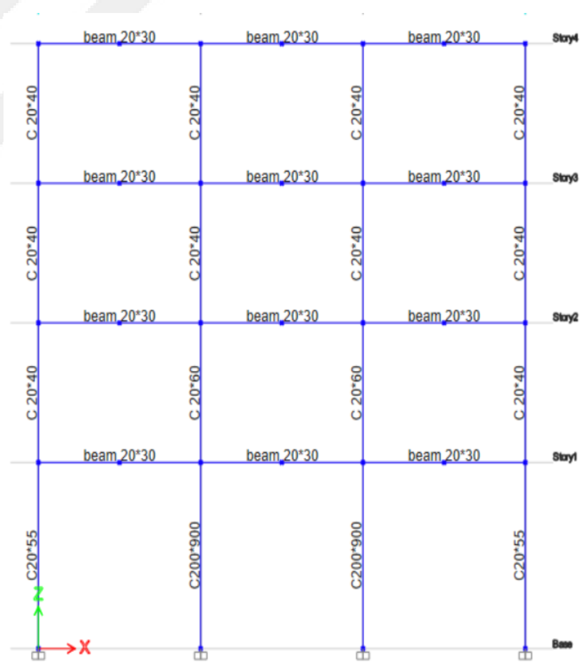


Figure 4.38: Concrete Building 3.



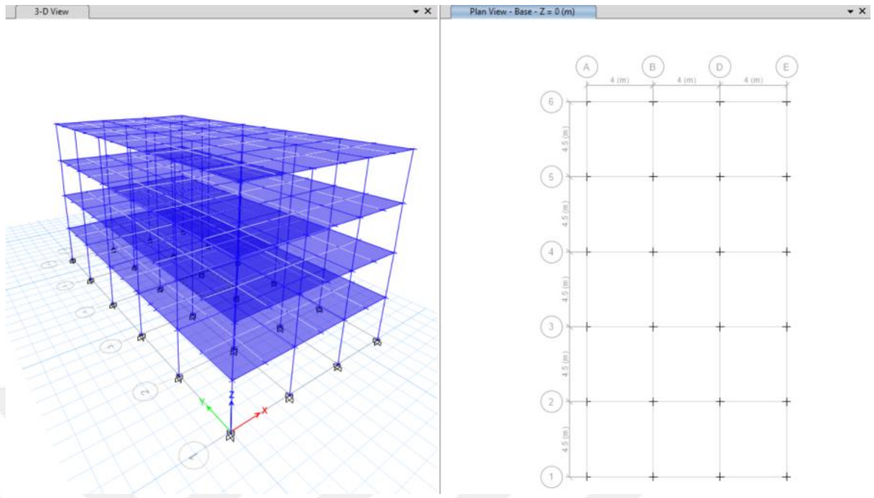


Figure 4.40: Layout Plan for Solid Slabs Buildings

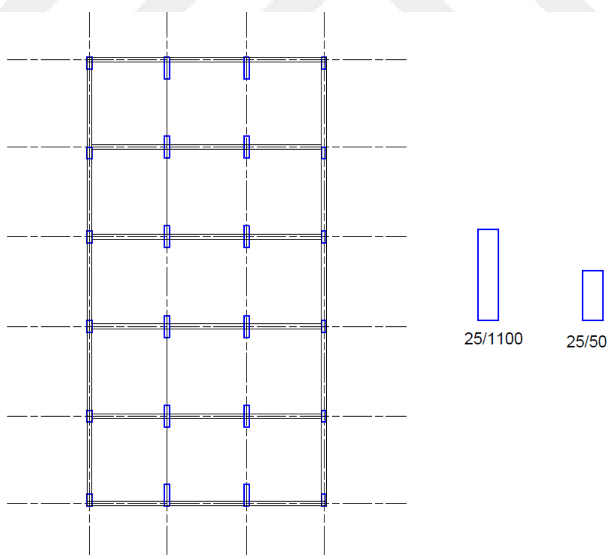


Figure 4.41: Layout Plan for Solid Slabs Buildings

Gravity

Solid 1 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	20.958	1.979
Floors	51.03	3.37744
Foundation	18.144	0.43363

Solid 2 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	20.958	3.959
Floors	114.759	6.82176
Foundation	23.52	0.56661

Solid 3 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	64.03668	6.053
Floors	153.09	10.2661
Foundation	36.456	0.86355

Solid 4 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	89.58354	8.516
Floors	204.12	13.7104
Foundation	44.5	1.3029

Lateral

Solid 1 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	42.66	5.277
Floors	51.03	3.737
Foundation	22.2	1.028

Solid 2 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	86.4	11.5
Floors	102.06	7.548
Foundation	35.2	0.8615

Solid 3 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	143.82	19.27
Floors	153.09	11.359
Foundation	42.4	1.03

Solid 4 story building	Concrete (m3)	Rebars (Ton)
Columns and beams	208.62	27.17
Floors	204.12	15.17
Foundation	52.55	1.405

Table 2.13: Input of Solid Structure in Athena Impact Estimator V5.2

	Outer Columns (12)	VOLUM	STEEL	fie	INNER COLUMNS (12)	VOLUM	STEEL		Stirrups
STORY1	25X60	4.32	2544	10Ø18	25X110	9.9	6842	18Ø22	Ø10/15
STORY2	25X60	4.32	2010	10Ø16	25X110	9.9	4580	18Ø18	Ø10/15
STORY3	25X60	4.32	2010	10Ø16	25X100	9	4580	18Ø18	Ø10/15
STORY4	25X60	2.88	2544	10Ø18	25X100	9	5654	18Ø22	Ø10/15

BEAM	LENGTH	VOLUME
25*50	162	20.25

	LENGTH	BOTTOM	UPPER	
BEAM1	48	367	430	2Ø16 , 2Ø18
BEAM 2	24	470	500	2Ø18 , 2Ø18
BEAM 3	90	394	485	2Ø16 , 2Ø18

	LENGTH	BOTTOM	UPPER	Bottom , Upper
BEAM1	48	394	542	2Ø16 , 2Ø18
BEAM 2	24	676	693	2Ø22 , 2Ø22
BEAM 3	90	534	620	2Ø18 , 2Ø20

	LENGTH	BOTTOM	UPPER	Bottom , Upper
BEAM1	48	452	599	2Ø18 , 2Ø20
BEAM 2	24	829	836	2Ø24 , 2Ø24
BEAM 3	90	652	739	2Ø22 , 2Ø22

	LENGTH	BOTTOM	UPPER	Bottom , Upper
BEAM1	48	425	564	2Ø18 , 2Ø18
BEAM 2	24	743	754	2Ø22 , 2Ø22
BEAM 3	90	578	676	2Ø20 , 2Ø22

Foundation	Outer (16)	Inner (8)
Dead	333 KN	685 KN
Live	58 KN	145 KN
Slab Thickness	18cm	

Table 3.14: Solid Slab Buildings Elements Dismission Used in ETABS19

Given Data

Materials information	Column information	Soil information
C30	D.L. = 481.12 KN	Class A
	L.L. = 60.40 KN	γs = 18.0 KN/m^3
Fy = 420 Mpa	a = 0.40 m	Df = 1.50 m
Cc = 50 mm	b = 0.20 m	h = 400 mm

Determination of Footing dimensions

$P_o = P_{D.L.} + P_{L.L.} =$ 541.5 KN

$\gamma_a = (\gamma_c + \gamma_s)/2 =$ 21.5 KN/m^3

$q_{na} = q_{all} - \gamma_a D_f =$ 117.8 KN/m^2

$A = P_o / q_{na} =$ 4.60 m^2

L = 2.80 m

B = 2.60 m

$A_f = LB =$ 7.2 m^2

$q_{act} = P_o / A_f =$ 117.7 KN/m^2 < qna ..... safe

Determination of Ultimate design forces

$P_u = 1.2\ P_{D.L.} + 1.6\ P_{L.L.} =$ 674.0 KN

$q_s = P_u / A_f =$ 146.5 KN/m^2

Assume footing thickness (h) = 400 mm

Then effective footing depth (d) = h - Cc - Ø = 338 mm

Check of wide beam action

$\phi = 0.75$

$V_u = q_s B (L/2 - a/2 - d) =$ 179.3 KN

$\phi V_n = \phi\ 0.17 \sqrt{f'c}\ B\ d =$ 422.2 KN > Vu ..... safe

$V_u = q_s L (B/2 - b/2 - d) =$ 189.4 KN

$\phi V_n = \phi\ 0.17 \sqrt{f'c}\ L\ d =$ 485.6 KN > Vu ..... safe

Check of two way action

bo = 2 (a + b + 2d) 2.55 m

$\beta = a / b$ 2.00

αs = 40 interior column

$$\frac{fVn}{\sqrt{f'c}\ bo\ d} = \text{the minimum of} \begin{cases} 0.17\,(1 + 2/\beta) = 0.34 \\ 0.083\,(\alpha_s\, d / bo) + = 0.61 \\ 0.33 = 0.33 \text{ (governs)} \end{cases}$$

Vu = qs (LB - (a + d) (b + d) 615.8 KN

$\phi Vn = \phi * 0.33 \sqrt{f'c}$ bo d = 1045.9 KN > Vu ..... safe

Determination of footing reinforcement

Assume tension controlled section (ϕ = 0.9)

β_1 = 0.85

ρmin = 0.0018

$$\rho max = 0.75 \frac{0.85 f'c}{fy} \beta_1 \left[\frac{600}{600 + fy} \right] = 0.0182$$

Long direction

Mu = qs B (L - a)^2 /8 132.2 KN.m.

$$Rn = \frac{Mu}{\phi B d^2} = 0.643$$

$$\rho req = \frac{0.85 f'c}{fy} \left[1 - \sqrt{1 - \frac{2Rn}{0.85 f'c}} \right] = 0.0016$$

$\rho gross = \rho req$ (d / h) = 0.0013 $\rho < \rho$ min......take $\rho = \rho$ min

As = ρ B d = 1216.8 mm^2

Use 11 Ø12 (As = 1243.4 mm^2)

Bars spacing = 189 mm < 450 mm......safe

Use minimum reinforcement

Short direction

Mu = qs L (B - b)^2 /8 136.5 KN.m.

$$Rn = \frac{Mu}{\phi L d^2} = 0.6204$$

$$\rho_{req} = \frac{0.85 f'c}{fy}\left[1 - \sqrt{1 - \frac{2Rn}{0.85 f'c}}\right] = 0.0015$$

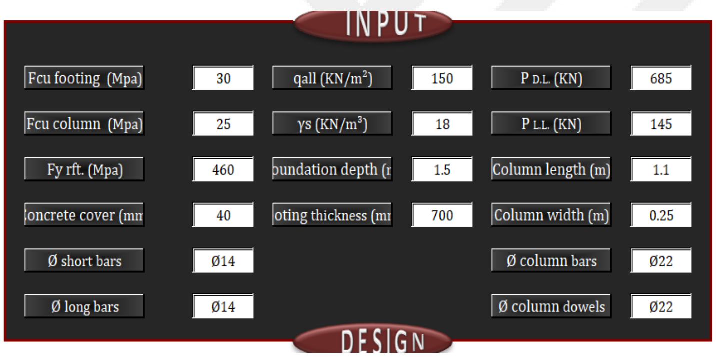
$\rho_{gross} = \rho_{req}$ (d / h) = 0.0013 $\rho < \rho$ min......take $\rho = \rho$ min

As = ρ L d = 1349.6 mm^2

Use 12 Ø12 (As = 1356.5 mm^2)

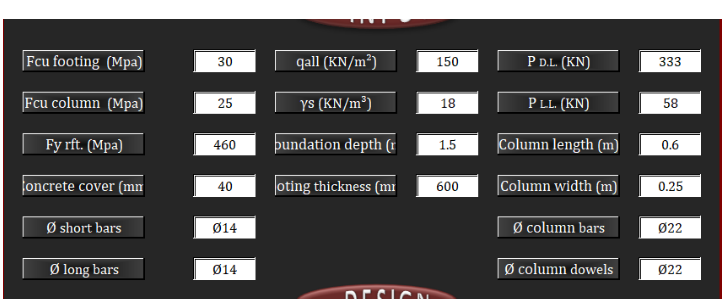
Bars spacing = 199 mm < 450 mm......safe

Final Results



Dimensions			Reinforcement	
L (m)	B (m)	h (m)	Long steel	Short steel
2.80 m	2.60 m	0.70 m	18 Ø14	19 Ø14

Figure 4.42: Input/Output of Inner Foundation



Dimensions			Reinforcement	
L (m)	B (m)	h (m)	Long steel	Short steel
2.00 m	1.80 m	0.60 m	11 Ø14	12 Ø14

Figure 4.43: Input/Output of Outer Foundation

Design of reinforced concrete building is based on many elements to be able to obtain the best sustainable and economical approach. The design of buildings that has been utilized in this study is done by using ETABS 19. The materials, for all reinforced concrete buildings have considered the same materials, whilst the materials which been used in steel structure has the same materials.

The table (4.15) shows the materials used in reinforced concrete structures.

RC Material	**4000psi**	
Modulus of Elasticity of concrete	24855.58	MPA
Rebars grade	A615Gr60	
Modulus of Elasticity of Rebars	199948	MPA
Steel grade	S420	

Table 4.15: Buildings Materials Used in ETABS19

The displacements obtained at the top of the building for ASCE7 code presented the plot below and combined a Figure (4.44), these displacements are found both spectral analyses considered CQC rule of modal analysis

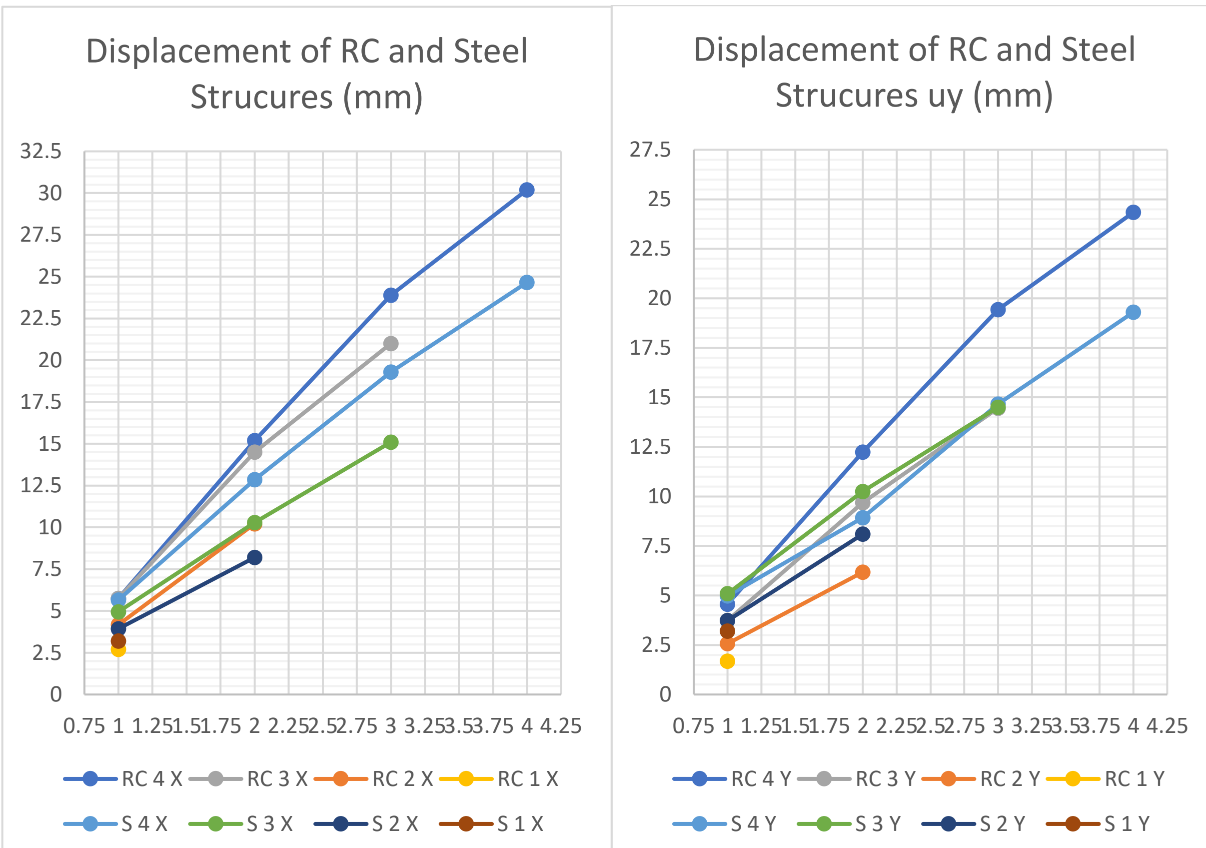


Figure 4.44: Displacement of RC and Steel Structures (mm)

The ASCE7 specified that the story drift ratio shall not be less than 0.025h if the initial period is less than 0.7, and 0.020 h if the primary is more than that.

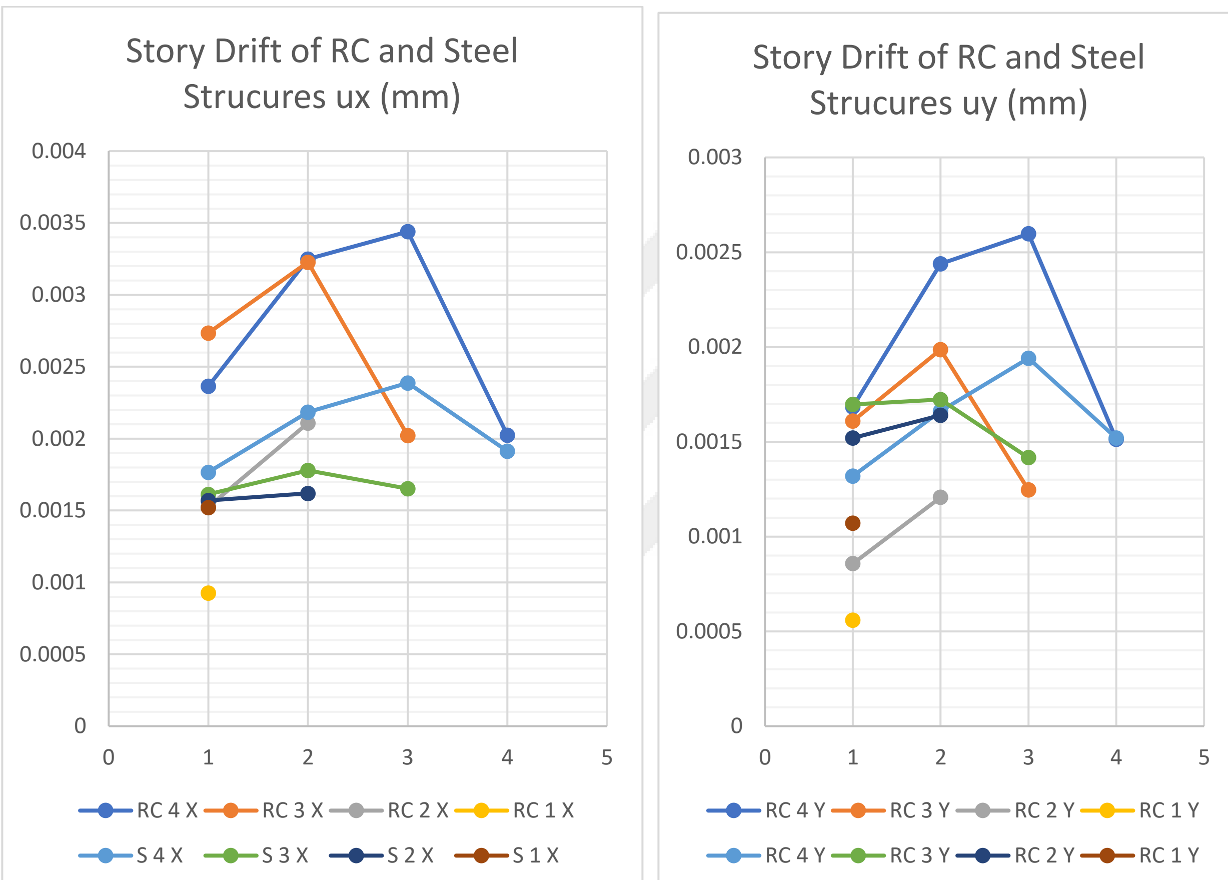


Figure 4.45: Story Drift of RC and Steel Structures (mm)

4.4.2 *Metal* Building Structural Design

B	
12mWx22.5mL	
Office Building	
USA	
Composite Steel Structure	
Number of stories: 1	Number of stories: 2
Total Height: 3	Total Height: 6
Roof Slop: 0	Roof Slop: 0
Interior Columns: 2	Interior Columns: 2
Total Columns: 12	Total Columns: 12
Roof Covering: Concrete	Roof Covering: Concrete
Number of stories: 3	Number of stories: 4
Total Height: 9	Total Height: 12
Primary Spacing between frames (BAY): 7.5 m X 6 m	Primary Spacing between frames (BAY): 7.5 m X 6 m
Roof Slop: 0	Roof Slop: 0
Interior Columns: 2	Interior Columns: 2
Total Columns: 12	Total Columns: 12

Table 4.16: Steel Structure Design

The steel is being modeled and designed by the following characteristics:

The steel structures building take place in location: New York City.

The considered height of the buildings is: 3 m - 6 m- 9 m and 12m. consisting of 4 different heights of buildings.

• Building area: 270 square meters of a ground floor plan

Category Study	Bay in X	Bay in Y
B	6	7.5

Table 4.17: Steel Bays Dimension

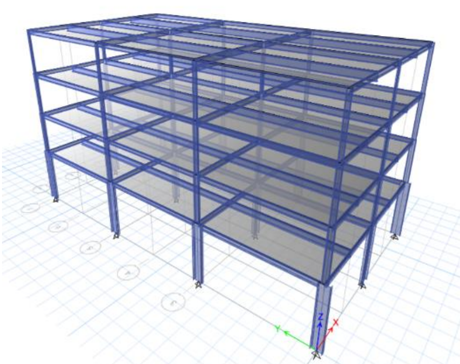


Figure 4.46: Non-Bracing System

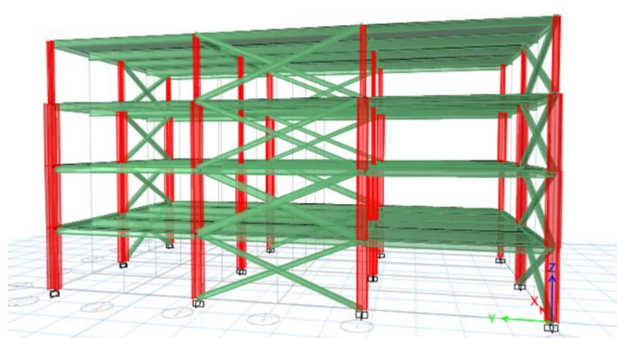


Figure 4.47: Steel Braced System

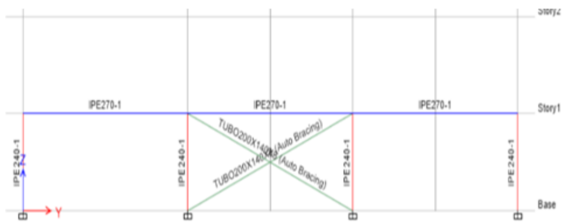


Figure 4.48: Steel Building 1.

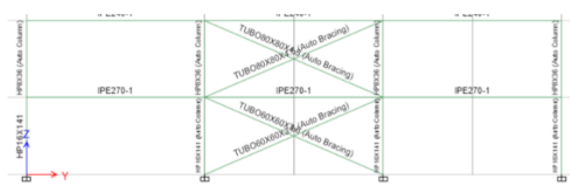


Figure 4.49: Steel Building 2.

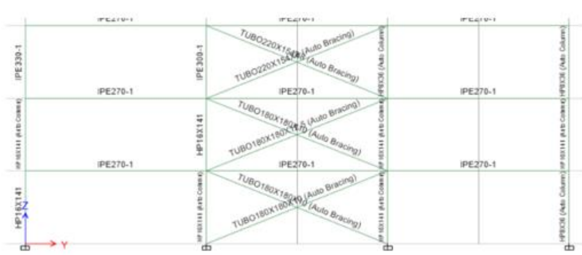


Figure 4.50: Steel Building 3.

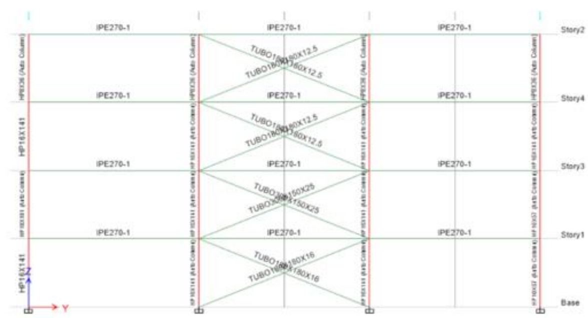


Figure 4.51: Steel Building 4.

Gravity

Steel 1 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		10.12323
Floors	17.01	3.70266
Foundation	7.392	0.1818

Steel 2 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		21.27901
Floors	34.02	7.40532
Foundation	15.78	0.3642

Steel 3 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		31.4844
Floors	51.03	11.10798
Foundation	22.89	0.62418

Steel 4 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		41.98581
Floors	68.04	14.81064
Foundation	36.7836	0.88362

Lateral

Steel 1 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		11.48461
Floors	17.01	3.70266
Foundation	8.568	0.21008

Steel 2 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		30.20698
Floors	34.02	7.40532
Foundation	16.1448	0.42117

Steel 3 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		48.96258
Floors	51.03	11.10798
Foundation	25.032	0.5959

Steel 4 story building	Concrete (m3)	Wide Flange (Ton)
Columns and beams		71.59345
Floors	68.04	14.81064
Foundation	37.0944	1.01202

Table 5.18: Input of Steel Structure in Athena Impact Estimator V5.2

CHAPTER 5
RESULTS AND DISCUSSIONS

5.1 Results

Building field contributes to a large extent in the greenhouse gas emissions. This contribution is increasing in USA where many new buildings are built every year. Based on that, the paper applies life cycle assessment technics to study the environmental emissions of construction processes. This study will make it clearer for the persons who have a response to the construction process to choose a good plan for construction so that the environmental emissions will be reduced. Earthwork construction has been considered as a study area. To do that, some important data is needed such as location, amount, equipment etc. The result shows that to reduce the earthwork environmental emissions, one should try to reduce the dust that comes from the construction process, reduce the using of steel and try to reuse water as well as concrete waste.

The results provided by the Athena Program for Building Impact are estimated from data generated on the tire life cycle impact of each construction phase. Among those criteria that were taken into consideration are the impact and risk of framework structures on increased global warming potential, human toxicity potential, nutrient augmentation, and fossil fuel depletion. The figures 5.1 and 5.2 show the effect of the four-story metal and concrete structures, Group A, on the environment for a period of 60 years.

Based on the outputs obtained from Athena and the comparison between the impact of metal buildings and concrete buildings in most cases, concrete buildings leave a greater impact on the environment and more emissions of carbon dioxide, as shown in Figure 5.1, it has formed a quantity of equivalent dioxide. Carbon 1.73E+05 Kg CO_2 eq, leaving a significant impact on the increase in global warming events with an increase 52% of the metal counterpart, whose quantity is estimated at 1.14E+05 Kg (carbon dioxide equivalent)

The concrete building produced an amount of 6.54E+02 kg (carbon dioxide equivalent), which relates to the effects of acidification Potential, and more than 5.6 E+02 Kg (SO2 equivalent) were produced. The concrete building left a greater impact on the environment and climate change as a result of producing more quantities of CO_2, which is the main reason for reducing the PH. The impact of the concrete buildings on leaves more impacts on smog potential as 29% more than the steel buildings as it only produces 1.10E+04 Kg of O_2equivalent.

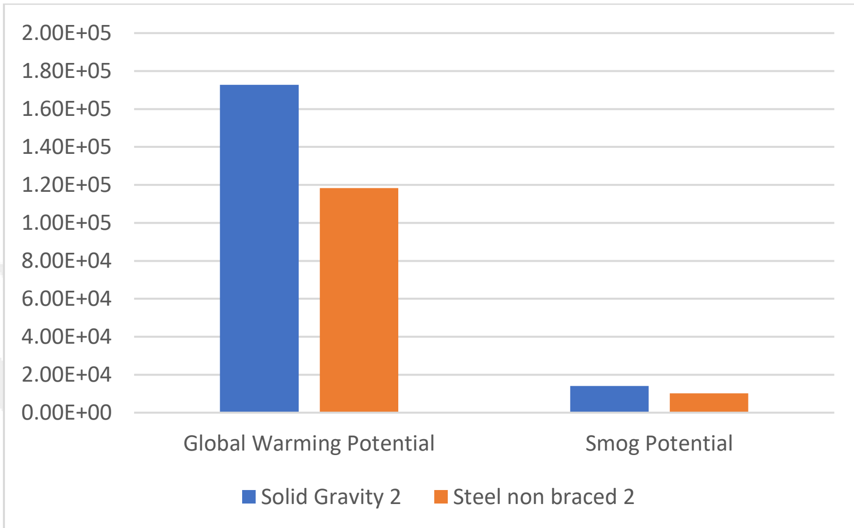


Figure 5.1: Impact of RC & Steel Building (4story) – Gravity on GWP and SP

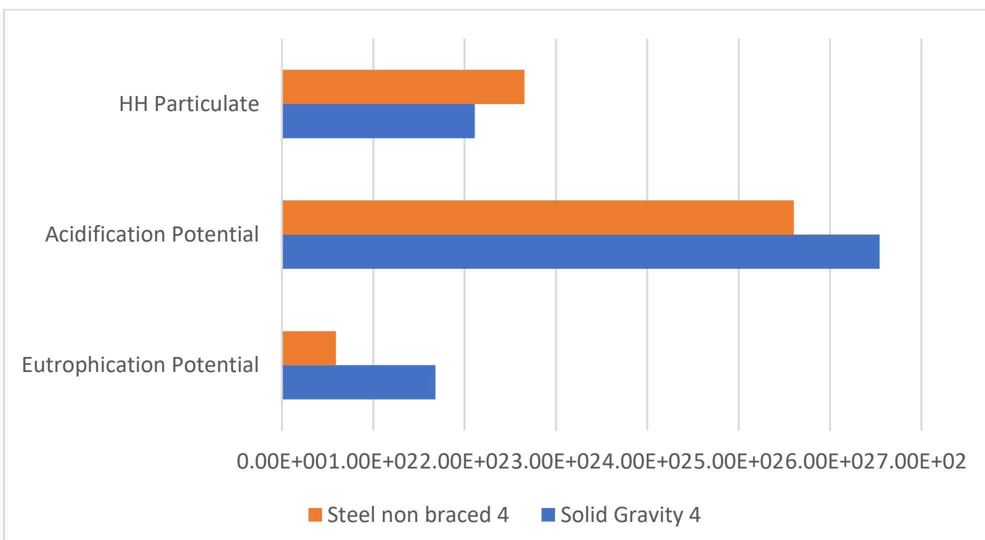


Figure 5.2: Impact of RC & Steel Building (4story) - Gravity on EU, AP, and HH

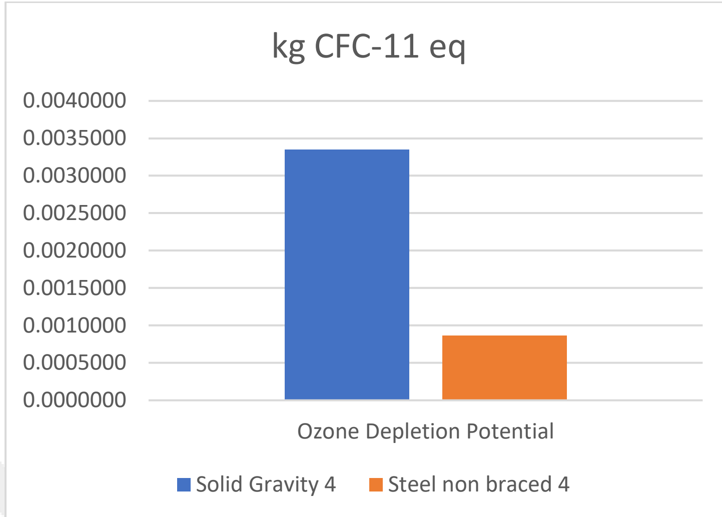


Figure 5.3: Impact of Figure of RC & Steel Building (4story) - Gravity on Ozon Depletion

In figure 5.3, the consumption of concrete buildings and the Ozon depletion of renewable resources is greater than the steel building by 258% and by 3.334E-03 kg CFC-11 eq to 8.64E-04, leaving a more harmful impact on the ecosystem than the steel sector.

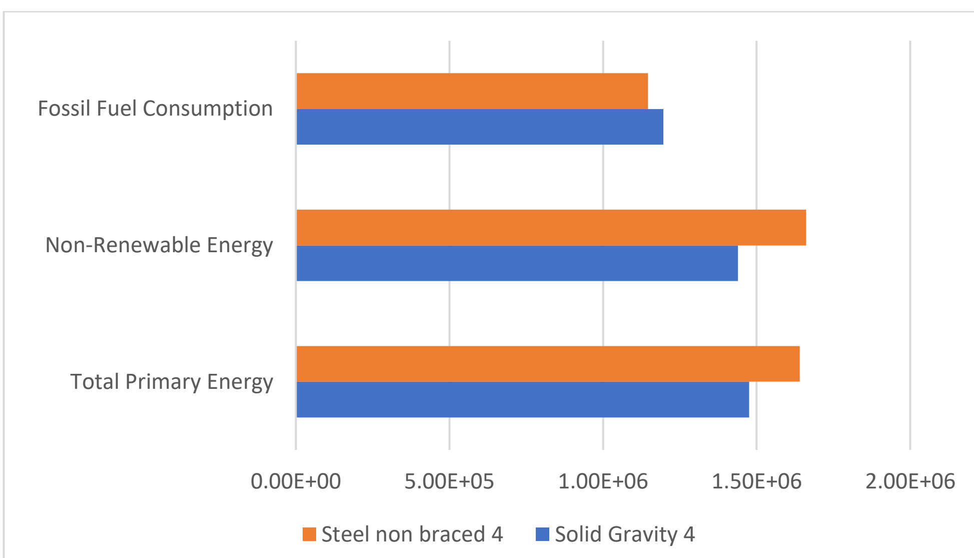


Figure 5.4: Impact of Figure of RC & Steel building (4story) - Gravity on Ozon depletion on Total Primary Energy, On-renewable Energy and Fossil Fuel Consumption

From figure 5.4, The contribution of steel structure can have bigger impact on the environment as it consumes more of nonrenewable energy, primary and fossil consumption. The fossil consumption of RC building is 4% more than fuel consumption of the steel. As the Non-renewable energy, the steel consumes 1.66E+06 MJ of energy while concrete building consumes 1.44E+06MJ. As in total Primary energy, the steel shows higher impact with 15% more than concrete.

The results are shown in the figure 5.5, the effect of increasing the number of floors and their impacts on the environment under the influence of horizontal force on the four concrete buildings. It appears that the amount of carbon is directly proportional to the increase in the number of floors by 97% between the first and second floors as amount 6.38E+04E to 1.25E+5E kg of CO_2 eq with a less increase between the second and third by 55% as amount 1.25E+05 to 1.95E+05 kg of CO_2. The amount of equivalent CO_2 of 4 story buildings at height 12m has less impact ratio in comparison to the 3story buildings. However, the amount of CO_2 which 4 story buildings produce is less impact in comparison of the ratio between 2^{nd} and 3rd environment by 42%. The analysis hasn't considered the transportation fuel to make the comparison comparable with a neglect of stage B of the LCA.

With increasing the number of buildings story, more than three-story (above 9 m) the impact slightly decreases by increasing the fourth story. If the impact ratio of the four-story buildings to the three-story buildings is considered, it shows the story increment is slightly reduced, the impacts of concrete buildings on all outputs; GW, AP, HH, Ozone, total energy have less impact ratio between the Athena output to the ratio of (1st story impact multiply by buildings story)

Unit	Solid lateral 1	Solid lateral 2	Solid lateral 3	Solid lateral 4	LCA Measures
kg CO2 eq	**6.38E+04**	**1.25E+05**	**1.95E+05**	**2.76E+05**	Global Warming Potential
kg SO2 eq	**2.36E+02**	**4.65E+02**	**7.22E+02**	**1.02E+03**	Acidification Potential
kg PM2.5 eq	**8.53E+01**	**1.72E+02**	**2.65E+02**	**3.72E+02**	HH Particulate
kg N eq	**5.60E+01**	**1.08E+02**	**1.69E+02**	**2.41E+02**	Eutrophication Potential
kg CFC-11 eq	**1.10E-03**	**2.12E-03**	**3.31E-03**	**4.72E-03**	Ozone Depletion Potential
kg O3 eq	**4.87E+03**	**9.52E+03**	**1.48E+04**	**2.10E+04**	Smog Potential
MJ	**5.49E+05**	**1.09E+06**	**1.69E+06**	**2.39E+06**	Total Primary Energy
MJ	**5.37E+05**	**1.07E+06**	**1.65E+06**	**2.33E+06**	Non-Renewable Energy
MJ	**4.62E+05**	**9.14E+05**	**1.42E+06**	**2.00E+06**	Fossil Fuel Consumption

Table 5.1: LCA Measures of Concrete Building - Lateral

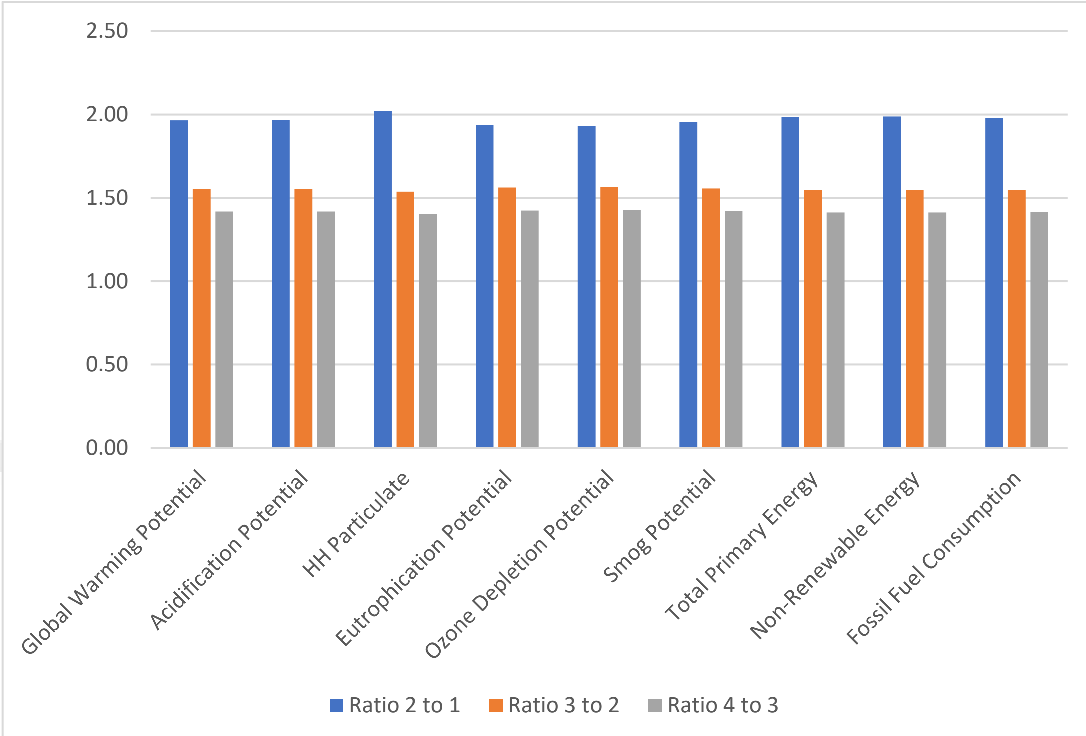


Figure 5.5: Ratio Impact of Concrete buildings (1,2,3, and 4)

Concrete/Steel	Ratio 2 to 1	Ratio 3 to 2	Ratio 4 to 3
Global Warming Potential	1.97	1.55	1.42
Acidification Potential	1.97	1.55	1.42
HH Particulate	2.02	1.54	1.40
Eutrophication Potential	1.94	1.56	1.42
Ozone Depletion Potential	1.93	1.56	1.43
Smog Potential	1.95	1.56	1.42
Total Primary Energy	1.99	1.55	1.41
Non-Renewable Energy	1.86	1.50	1.37
Fossil Fuel Consumption	1.86	1.50	1.36

Table 5.2: Ratio of Floor Increment of RC Building - Lateral

It is noticeable that the curve of GW curve ratio between the story is the ratio of 2^{nd} story to 1^{st} story buildings, 3story buildings to 2story buildings and the 4story buildings to 3 story buildings. The ratio between 3^{story} buildings and 4^{story} buildings are 1.42 As what the figure 5.6 shows

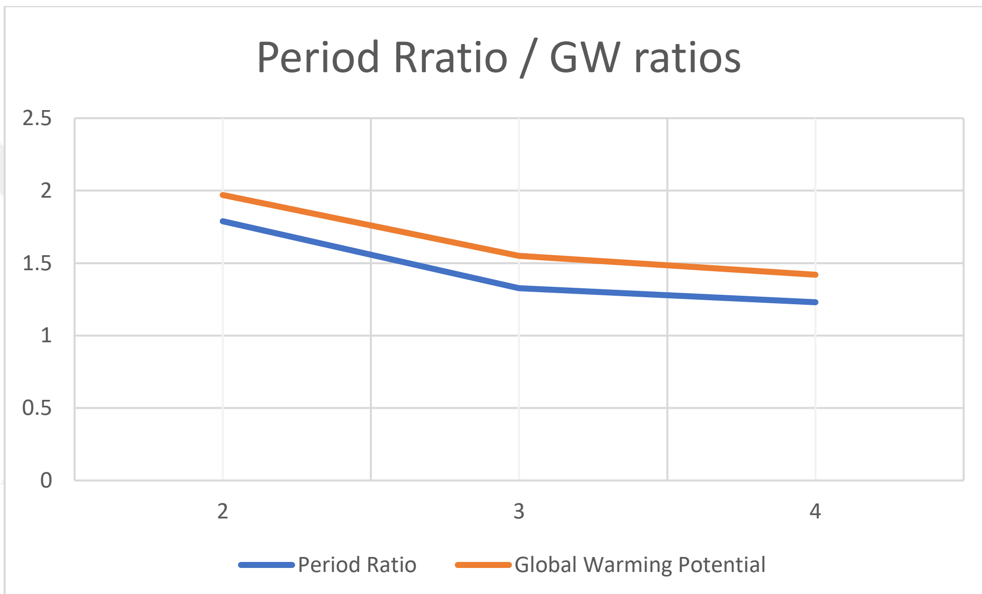


Figure 5.6: Period Ratio - GW Ratio of RC building- Lateral

Concrete/Steel	Period Ratio	Global Warming Potential
Ratio 2 to 1	1.789	1.97
Ratio 3 to 2	1.327	1.55
Ratio 4 to 3	1.23	1.42

Table 5.3: Period Ratio - GW Ratio of RC Building- Lateral

The results of the comparison between two number of buildings (2 story buildings) which subjected to lateral load and Gravity load only. The figure 5.7 shows that, the buildings which designed under the influence of seismic forces based on the ASCE7-16 code produces more carbon dioxide emissions, it produces 1.25E+05 kg of CO_2 as equivalent to global warming emission, while the amount produces 8.23E+04 kg of CO_2 when the building isn't designed under any lateral load.

Also, the results indicate that the ozone-affecting emissions of the concrete buildings that were designed under seismic studies, amounted to 0.00212 kg CFC equivalent tons of carbon dioxide, which 33% more impact on environment to a non-seismic design.

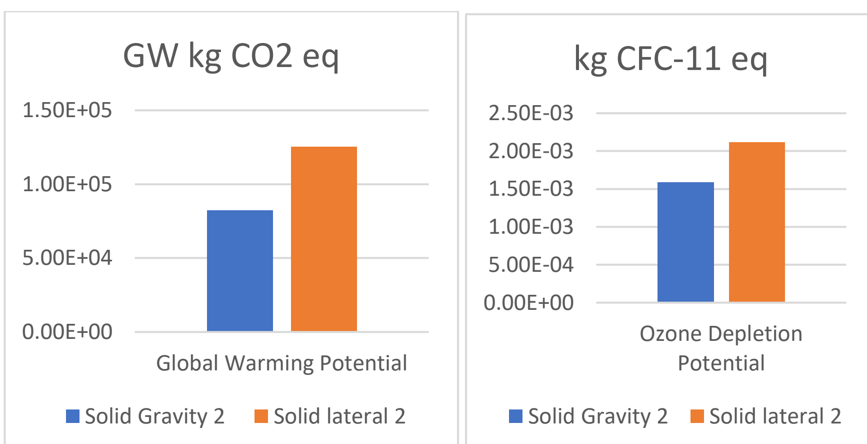


Figure 5.7: Impact of RC Building Under Non-Lateral and Lateral Load Design on GW and Ozone

LCA Measures	Unit	Solid Gravity 2	Solid lateral 2
Global Warming Potential	kg CO2 eq	**8.23E+04**	**1.25E+05**
Ozone Depletion Potential	kg CFC-11 eq	**1.59E-03**	**2.12E-03**

Table 5.4: Impact of Concrete Buildings (Gravity-Lateral)

Concrete/Steel	**Global Warming Potential (Kg.CO_2)**
Steel 4 Gravity	1.18E+05
Steel 4 Lateral	1.51E+05

Table 5.5: Compression Between Braced and Non-Braced Steel Structure on GW

Based on what was deduced from the data from the Athena program on metal buildings, studying the results shown in figure 5.8. Two steel buildings were chosen to be constructed in two different regions, the first region is subjected to seismic, while the second one is non seismic region. The study compares the impact of a braced steel building and another building that is not braced, the braced one is subjected under lateral forces resulting from the site design of a four-story building. The graph shows that constructing steel buildings in seismic region has more impact on GW as it produces 1.14E+05 kg CO_2 equivalent to carbon dioxide, while the increment of the impact can be measured as 31% more than the steel building which constructed in non-seismic region

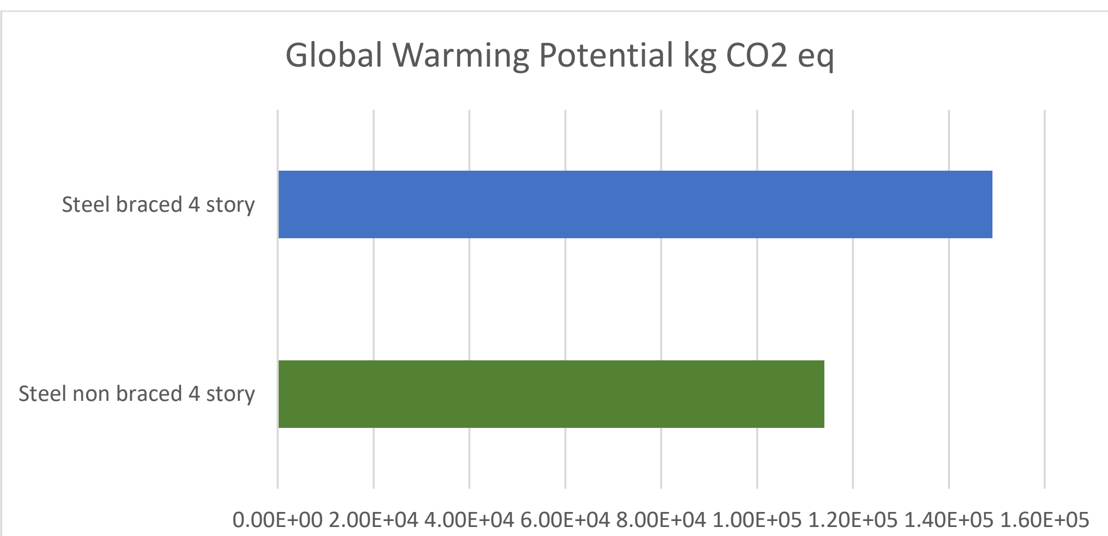


Figure 5.8: Comparison Between Braced and Non-Braced Buildings on GW (4story)

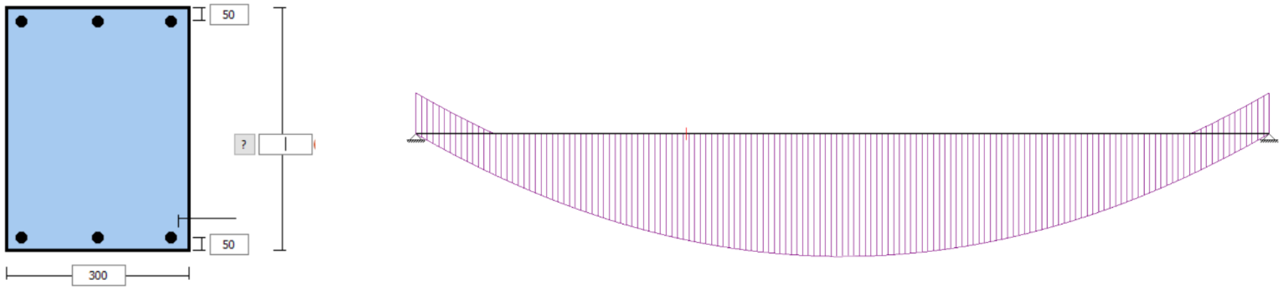


Figure 5.9: Moment Section 80KN.m

CASE	WIDTH CM	DEPTH CM	REINFORCEMENT AREA CM2	Ø	CONCRETE VOLUME	STEEL WEIGHT KG
CASE1	30	30	8.86	8Ø18	0.27	48
CASE2	30	35	7.04	6Ø18	0.315	36
CASE3	30	40	5.88	8Ø14	0.36	29.04
CASE4	30	45	5.06	4Ø18	0.405	24
CASE5	30	50	4.45	6Ø14	0.45	21.78

Table 5.6: Quantity of Rebars and Concrete Due to The Depth of The Beam

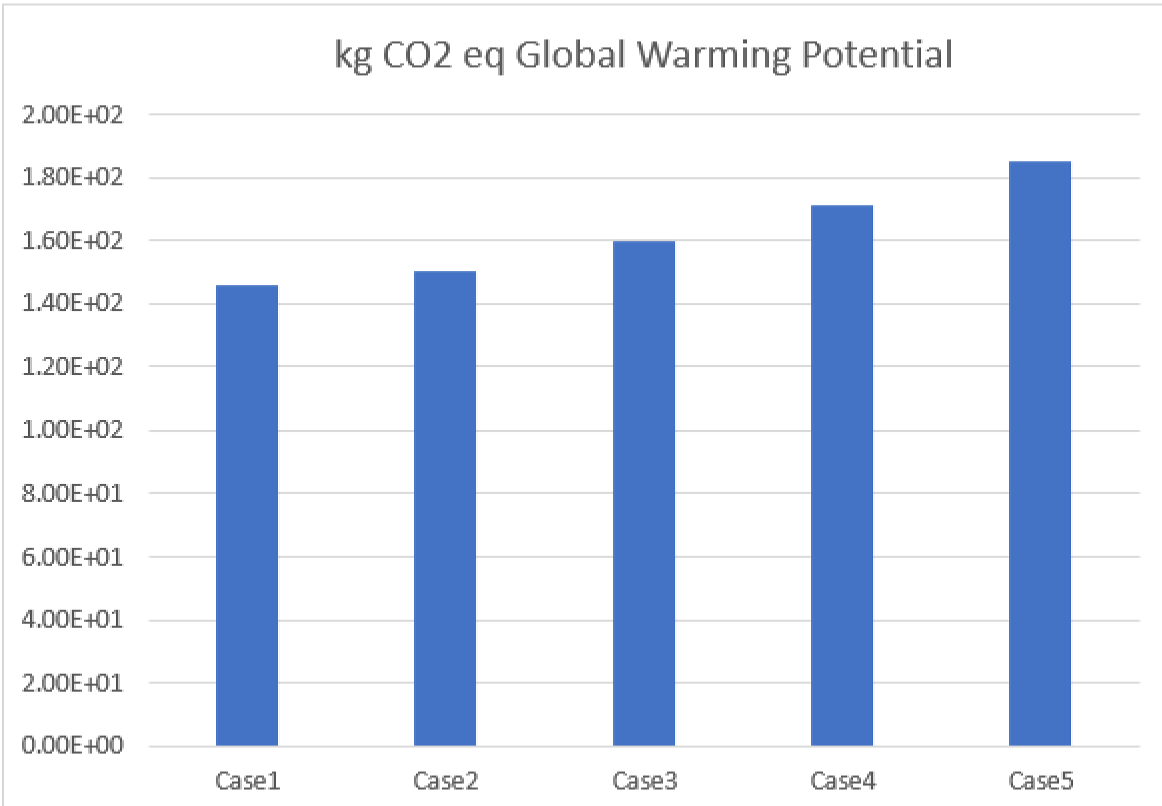


Figure 5.10: GWP of Beam Section

As what the graph 5.10 shows, the global warming potential increased 27% from case 1 to case 5, producing 1.85E+02 and 1.46E+02 kg of CO_2 respectively, when the depth of concrete increased 60%. The Global warming potential is slightly increased in case 2.

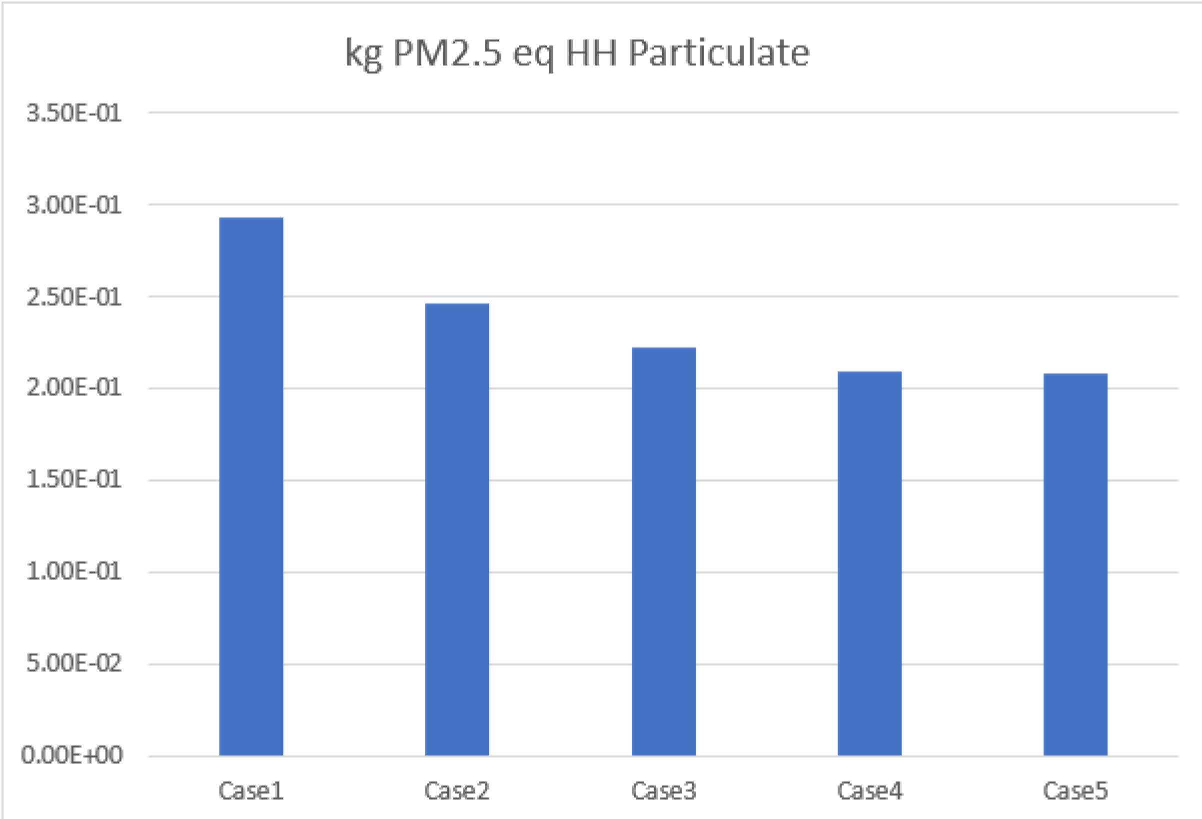


Figure 5.11: HH of Beam Section

Regarding to the graph 5.11, the case 1 has the greatest impact of HH particulate as it produces 2.93 E-01 of PM2.5 kg equivalents to HH particulate. While case 4 is equal to case5 as they both produces the same amount of 2.09 E-01 of Kg PM2.5.

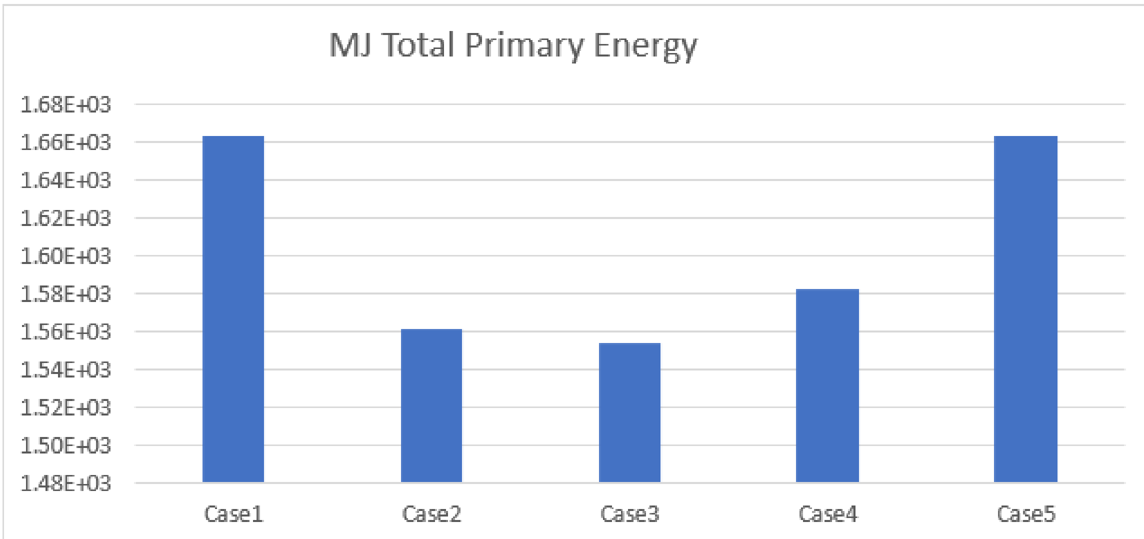


Figure 5.12: Total Primary Energy of Beam Section

As the results shown in the graph 5.12, the primary Energy consumption isn't related to the depth of the concrete as it's related to the whole section of the beam. Case1 and case 2 have the greatest consumption of total Energy as case consume of 1.66 E03 Mj of total primary energy while case 5 consumes the same. In the graph, the case 3 has the lowest consumption which makes it ideal design in consumption, it only consumes 1.55E03 Mj.

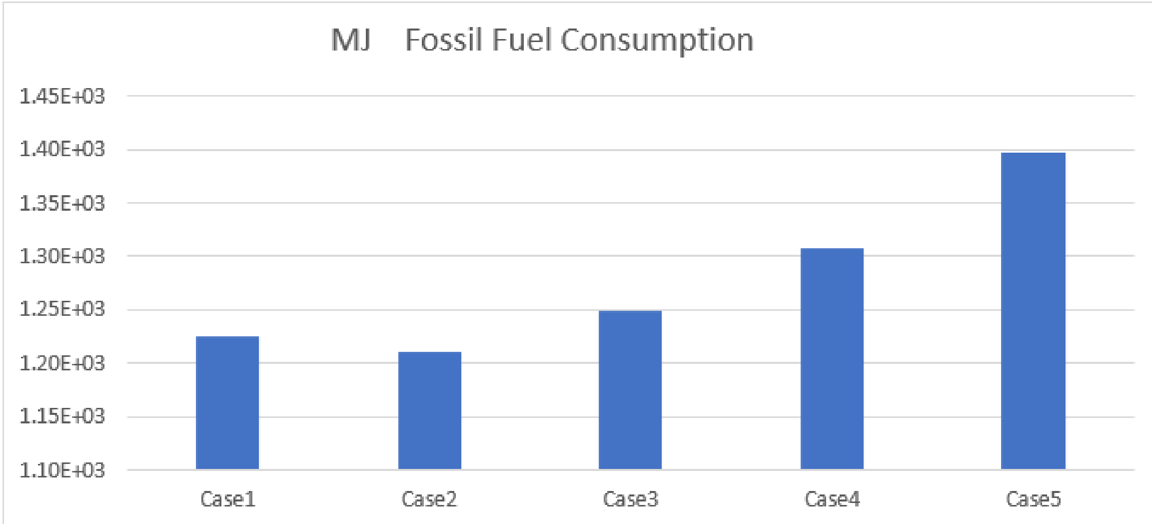


Figure 5.13: The Impact of Beam Section on Fossil Fuel Consumption

The fossil fuel consumption in figure 5.13 shows that case 5 has the greatest consumption among the other cases, it consumes 14% more when the depth of the beam is increased from 30cm to 50cm. However, in case 2 has less fossil consumption than the other cases.

Unit	LCA Measures	Case1	Case2	Case3	Case4	Case5
kg CO_2 eq	Global Warming Potential	1.46E+02	1.50E+02	1.60E+02	1.71E+02	1.85E+02
kg SO2 eq	Acidification Potential	6.80E-01	6.93E-01	7.30E-01	7.76E-01	8.36E-01
kg PM2.5 eq	HH Particulate	2.93E-01	2.46E-01	2.23E-01	2.09E-01	2.09E-01
kg N eq	Eutrophication Potential	1.13E-01	1.29E-01	1.45E-01	1.62E-01	1.79E-01
kg CFC-11 eq	Ozone Depletion Potential	2.02E-06	2.35E-06	2.69E-06	3.02E-06	3.36E-06
kg O3 eq	Smog Potential	1.47E+01	1.57E+01	1.71E+01	1.85E+01	2.01E+01
MJ	Total Primary Energy	1.66E+03	1.56E+03	1.55E+03	1.58E+03	1.66E+03
MJ	Non-Renewable Energy	1.64E+03	1.54E+03	1.53E+03	1.55E+03	1.63E+03
MJ	Fossil Fuel Consumption	1.23E+03	1.21E+03	1.25E+03	1.31E+03	1.40E+03

Table 5.7: LCA Measure of Beam Impact

CHAPTER 6
CONCLUSIONS

The study conducted the evaluation of frame structural buildings as a whole-building life cycle analysis of 32 buildings utilizing Athena Building Impact Estimator in USA as a general country and LA regions to come up with final impact indicators from the life cycle from stage A to stage C. Results showed that the substituting of steel for concrete would reduce the impact of GW significantly. The emission of CO_2 produced in concrete buildings was 52 % more than the emissions produced of steel buildings. So, the steel structural building is superior to the concrete structural building. The total primary energy consumption and the particles left in the air in use phase of the steel buildings has larger impact in comparison to another type of buildings. The result shows that constructing a concrete building in A class earthquake region produces 52% of the CO_2 emission more than the buildings was chosen to be built in non-earth quack regions. The results also reported in this study can support the choice of building more story, to mitigate the environmental impact. It's shown in results the ideal depth can be designed is 40cm depth when it's loaded a high load.

- 4 story concrete buildings have a greater impact on the environment and emit more carbon dioxide. The concrete building produced an amount of 6.54E+02 kg (carbon dioxide equivalent), which relates to the effects of acidification potential, and more than 5.90E+-02 kg. RC building produced. 1.41E+05 kg of CO2 left a significant impact on the increase in global warming events with an increase of 29% of the metal counterpart.

- The beam is designed at 80 KNm and has a length of 3 m. The optimal depth occurs when the beam depth is 40cm, the reinforcement area is 5.88 cm2, and the reinforcement is 8Ø14 while the concrete volume is 0.45 m3. In example 3, as seen by figures 5.6, 5.11, and 5.12. If HH, GWP, and total primary into account are taken into study. Case number three is the best option.

- Constructing steel structures in seismic zone site class A, has a greater impact on GW because it creates 1.14E+05 kg CO_2equal to carbon dioxide, while the increase in impact is 31 percent more than constructing steel buildings in non-seismic zones.

- Buildings designed under the impact of seismic forces based on ASCE7-16 code emit more carbon dioxide, generating 101.25E+055E+04 kg of CO_2comparable to global warming emissions, compared to 8.23E+04 kg of $CO_2$when the structure is not designed under any lateral pressure.

  Furthermore, the results show that the ozone-depleting emissions of concrete structures developed under seismic research amounted to 0.00212 kg CO_2equivalent tons of carbon dioxide, which is a 33 percent higher environmental effect than a non-seismic design.

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source Use Life Cycle Inventory Results Table by Life Cycle Stages (A to D)

Of 4 concrete story under lateral dynamic load

		PRODUCT (A1 TO A3)			CONSTRUCTION PROCESS (A4 & A5)	
MATERIAL	**Unit**	**Manufacturing**	**Transport**	**Total**	**Construction-Installation Process**	**Transport**
CARBON DIOXIDE, IN AIR	kg	696.7618	0	696.7618	15.03154	0
CLAY & SHALE	kg	4123.606	0	4123.606	206.1803	0
COAL	kg	19297.53	12.2263	19309.76	748.0307	11.07631
COARSE AGGREGATE	kg	772666.4	0	772666.4	38633.32	0
CRUDE OIL	L	6679.913	1009.475	7689.388	317.1565	614.7103
DOLOMITE	kg	2240.44	0	2240.44	38.09366	0
FERROUS SCRAP	kg	41251.97	0	41251.97	701.3712	0
GYPSUM (NATURAL)	kg	4274.906	0	4274.906	213.7453	0
GYPSUM (SYNTHETIC)	kg	13.29166	0	13.29166	0.664583	0
IRON ORE	kg	174.0098	0	174.0098	19.638	0
LIGNITE	kg	643.4628	0	643.4628	11.34312	0
LIMESTONE	kg	142646.2	0	142646.2	7097.841	0
NATURAL GAS	m3	7624.198	40.1862	7664.384	217.7924	36.40632
OTHER	kg	7354.312	0	7354.312	367.7156	0
PEAT	kg	1.167253	0	1.167253	0.058363	0
SAND	kg	0.000547	0	0.000547	2.73E-05	0
TIN ORE	kg	0.000113	0	0.000113	5.65E-06	0
URANIUM	kg	0.220814	0.000102	0.220916	0.006791	9.07E-05
WATER	L	1676311	0	1676311	66672.59	0
WOOD FIBER	kg	3346.751	0	3346.751	167.3375	0

	END OF LIFE (C1 TO C4)			BEYOND BUILDING LIFE (D)			TOTAL EFFECTS	
TOTAL	**De-construction, Demolition, Disposal & Waste Processing**	**Transport**	**Total**	**BBL Material**	**BBL Transport**	**Total**	**A to C**	**A to D**
15.03154	0	0	0	74.60528	0	74.60528	711.7933	786.3986
206.1803	0	0	0	0	0	0	4329.786	4329.786
759.107	35.39374	13.48341	48.87714	8766.306	0	8766.306	20117.74	28884.05
38633.32	0	0	0	0	0	0	811299.7	811299.7
931.8668	2907.729	1113.351	4021.08	-183.788	0	-183.788	12642.33	12458.55
38.09366	0	0	0	427.2466	0	427.2466	2278.534	2705.781
701.3712	0	0	0	0	0	0	41953.34	41953.34
213.7453	0	0	0	0	0	0	4488.651	4488.651
0.664583	0	0	0	0	0	0	13.95624	13.95624
19.638	0	0	0	16767.08	0	16767.08	193.6479	16960.72
11.34312	0	0	0	-586.178	0	-586.178	654.8059	68.62779
7097.841	0	0	0	-657.024	0	-657.024	149744.1	149087
254.1987	116.1539	44.31813	160.4721	-908.197	0	-908.197	8079.055	7170.859
367.7156	0	0	0	0	0	0	7722.028	7722.028
0.058363	0	0	0	0	0	0	1.225616	1.225616
2.73E-05	0	0	0	0	0	0	0.000574	0.000574
5.65E-06	0	0	0	-1E-12	0	-1E-12	0.000119	0.000119
0.006882	0.000287	0.00011	0.000397	-0.03621	0	-0.03621	0.228195	0.191984
66672.59	0	0	0	154767.2	0	154767.2	1742984	1897751
167.3375	0	0	0	0	0	0	3514.088	3514.088

		PRODUCT (A1 TO A3)	CONSTRUCTION PROCESS (A4 & A5)	USE (B2, B4 & B6)	END OF LIFE (C1 TO C4)	BEYOND BUILDING LIFE (D)	TOTAL EFFECTS	
EMISSION	**Unit**	**Total**	**Total**	**Total**	**Total**	**Total**	**A to C**	**A to D**
2-HEXANONE	mg	183.4153	27.38647	0	293.5244	0	293.5244	293.5244
ACETONE	mg	319.9527	43.8945	0	490.5348	0	490.5348	490.5348
ACIDS, UNSPECIFIED	mg	824.7912	41.23956	0	866.0308	0	866.0308	866.0308
ALUMINUM	mg	6262525	560322.1	0	7947712	0	7947712	7947712
AMMONIA	mg	1067526	87274.08	27562	1395116	27562	1395116	1422678
AMMONIA, AS N	mg	0.118941	0.005947	0	0.124888	0	0.124888	0.124888
AMMONIUM, ION	mg	70638.76	3539.455	0	74331.51	0	74331.51	74331.51
ANTIMONY	mg	3465.562	327.7362	0	4496.168	0	4496.168	4496.168
ARSENIC, ION	mg	32985.95	2418.765	0	38900.98	0	38900.98	38900.98
BARIUM	mg	29774788	4874566	0	50055482	0	50055482	50055482
BENZENE	mg	54610.44	7410.45	0	83273.77	0	83273.77	83273.77
BENZENE, 1-METHYL-4-(1-METHYLETHYL)-	µg	2807.003	419.1227	0	4492.111	0	4492.111	4492.111
BENZENE, ETHYL-	mg	3171.836	421.849	0	4789.21	0	4789.21	4789.21
BENZENE, PENTAMETHYL-	µg	2105.278	314.3471	0	3369.131	0	3369.131	3369.131
BENZENES, ALKYLATED, UNSPECIFIED	mg	1130.3	192.0184	0	1938.935	0	1938.935	1938.935
BENZOIC ACID	mg	28495.27	4254.711	0	45601.57	0	45601.57	45601.57
BERYLLIUM	mg	7976.027	441.8656	0	8613.635	0	8613.635	8613.635
BIPHENYL	µg	73182.18	12432.36	0	125537.7	0	125537.7	125537.7
BOD5, BIOLOGICAL OXYGEN DEMAND	mg	7469414	880905.2	129342.1	10681908	12934	10681908	10811250
BORON	mg	119956.4	14753.74	0	174473.9	0	174473.9	174473.9
BROMIDE	mg	6018583	898603.3	0	9631392	0	9631392	9631392
CADMIUM, ION	mg	6520.382	397.9611	226.941	7434.382	226.941	7434.382	7661.323

CALCIUM, ION	mg	1.92E+08	18579895	0	2.52E+08	0	2.52E+08	2.52E+08
CHLORIDE	mg	1.21E+09	1.61E+08	0	1.82E+09	0	1.82E+09	1.82E+09
CHROMIUM	mg	59920.42	9479.428	-412.189	99336.84	-412.189	99336.84	98924.65
CHROMIUM VI	µg	46680641	2361699	0	49168305	0	49168305	49168305
CHROMIUM, ION	mg	3165.957	605.4179	0	5790.649	0	5790.649	5790.649
COBALT	mg	94481.31	4785.872	0	99547.89	0	99547.89	99547.89
COD, CHEMICAL OXYGEN DEMAND	mg	26118819	1881424	-91498	32469839	-91498.9	32469839	32378340
COPPER, ION	mg	83260.21	4960.69	0	91850.37	0	91850.37	91850.37
CYANIDE	mg	244.5211	12.42739	0	257.8628	0	257.8628	257.8628
DECANE	mg	818.8164	122.2606	0	1310.373	0	1310.373	1310.373
DETERGENT, OIL	mg	24436.12	3551.702	0	38563.3	0	38563.3	38563.3
DIBENZOFURAN	µg	5341.155	797.5041	0	8547.566	0	8547.566	8547.566
DIBENZOTHIOPHE NE	µg	3459.695	206.339	0	3812.897	0	3812.897	3812.897
DISSOLVED SOLIDS	mg	4.96E+08	1.49E+08	74798	1.21E+09	74798.1 3	1.21E+09	1.21E+09
DOC, DISSOLVED ORGANIC CARBON	mg	1321033	67927.3	0	1427210	0	1427210	1427210
DOCOSANE	µg	30058.34	4488.096	0	48102.97	0	48102.97	48102.97
DODECANE	mg	1553.564	231.9676	0	2486.203	0	2486.203	2486.203
EICOSANE	mg	427.7367	63.86665	0	684.5162	0	684.5162	684.5162
FLUORENE, 1-METHYL-	µg	3196.887	477.3383	0	5116.055	0	5116.055	5116.055
FLUORENES, ALKYLATED, UNSPECIFIED	µg	65503.63	11127.91	0	112365.8	0	112365.8	112365.8
FLUORIDE	mg	195295	9765.139	0	205068.1	0	205068.1	205068.1
FLUORINE	µg	32684.26	5502.774	0	55788.91	0	55788.91	55788.91
HEXADECANE	mg	1695.716	253.1935	0	2713.697	0	2713.697	2713.697
HEXANOIC ACID	mg	5901.093	881.1111	0	9443.652	0	9443.652	9443.652
HYDROCARBONS, UNSPECIFIED	µg	4949606	247480.3	0	5197086	0	5197086	5197086
HYDROGEN CHLORIDE	mg	2491.33	124.5665	0	2615.896	0	2615.896	2615.896
HYDROGEN SULFIDE	mg	15776.19	788.978	0	16568.61	0	16568.61	16568.61
IRON	mg	28469923	1465137	-893550	32166458	-893550	32166458	31272908
LEAD	mg	31861.06	3130.017	-1190.37	42413.2	-1190	42413.2	41222.83

LEAD-210/KG	µg	0.002918	0.000435	0	0.004669	0	0.004669	0.004669
LITHIUM, ION	mg	11047171	599605.7	0	11827076	0	11827076	11827076
M-XYLENE	mg	969.0785	132.9757	0	1485.891	0	1485.891	1485.891
MAGNESIUM	mg	65680445	5035925	0	78672304	0	78672304	78672304
MANGANESE	mg	3761785	190931.3	0	3965486	0	3965486	3965486
MERCURY	µg	1353301	70378.8	0	1436123	0	1436123	1436123
METALLIC IONS, UNSPECIFIED	mg	0.01111	0.000556	0	0.011666	0	0.011666	0.011666
METHANE, MONOCHLORO-, R-40	µg	1130.64	168.8195	0	1809.389	0	1809.389	1809.389
METHYL ETHYL KETONE	µg	2261.199	337.6271	0	3618.649	0	3618.649	3618.649
MOLYBDENUM	mg	25844.04	1356.338	0	27491.73	0	27491.73	27491.73
N-HEXACOSANE	µg	18752.55	2800.008	0	30010.16	0	30010.16	30010.16
NAPHTHALENE	mg	511.4848	76.40866	0	818.749	0	818.749	818.749
NAPHTHALENE, 2-METHYL-	mg	444.9311	66.43406	0	712.0331	0	712.0331	712.0331
NAPHTHALENES, ALKYLATED, UNSPECIFIED	µg	18521.61	3146.497	0	31772.24	0	31772.24	31772.24
NICKEL	mg	443519.3	22865.45	722	469852.1	722	469852.1	470574.3
NITRATE	mg	4865351	243269.5	0	5108661	0	5108661	5108661
NITRATE COMPOUNDS	mg	0.00321	0.00016	0	0.00337	0	0.00337	0.00337
NITRIC ACID	mg	7.199456	0.359973	0	7.559428	0	7.559428	7.559428
NITROGEN	mg	89186293	4458135	1445031	93644668	1445031	93644668	95089700
O-CRESOL	mg	808.0757	120.6563	0	1293.181	0	1293.181	1293.181
OCTADECANE	mg	418.9253	62.55104	0	670.4154	0	670.4154	670.4154
OILS, UNSPECIFIED	mg	1092642	119321.3	0	1505826	0	1505826	1505826
P-CRESOL	mg	871.8533	130.1784	0	1395.242	0	1395.242	1395.242
PAH, POLYCYCLIC AROMATIC HYDROCARBONS	µg	66268.32	3313.416	0	69581.74	0	69581.74	69581.74
PENTANONE, METHYL-	mg	46.81685	14.06479	0	114.1234	0	114.1234	114.1234

PHENANTHRENE	µg	7012.638	1140.001	0	11742.41	0	11742.41	11742.41
PHENANTHRENES, ALKYLATED, UNSPECIFIED	µg	7679.819	1304.667	0	13174.07	0	13174.07	13174.07
PHENOL	µg	12295408	1839178	0	19709204	0	19709204	19709204
PHENOL, 2,4-DIMETHYL-	mg	786.8178	117.4823	0	1259.162	0	1259.162	1259.162
PHENOLS, UNSPECIFIED	mg	4208.547	400.8747	0	5462.003	0	5462.003	5462.003
PHOSPHATE	mg	15502104	774637.4	-2082.27	16276743	-2082.27	16276743	16274660
PHOSPHORUS	mg	1130.905	41.37919	-6315.5	1172.284	-6315.5	1172.284	-5143.21
RADIOACTIVE SPECIES, NUCLIDES, UNSPECIFIED	mg	4.9E+10	2.45E+09	0	5.15E+10	0	5.15E+10	5.15E+10
RADIUM-226/KG	µg	1.015414	0.151615	0	1.624995	0	1.624995	1.624995
RADIUM-228/KG	µg	0.005193	0.000774	0	0.008309	0	0.008309	0.008309
SELENIUM	µg	15783141	819109.7	0	16738550	0	16738550	16738550
SILVER	mg	67344.87	9227.276	0	103184.4	0	103184.4	103184.4
SODIUM, ION	mg	3.77E+08	47245781	0	5.53E+08	0	5.53E+08	5.53E+08
SOLIDS, INORGANIC	mg	374647.1	18732.36	0	393379.5	0	393379.5	393379.5
STRONTIUM	mg	3328817	318524.9	0	4337999	0	4337999	4337999
SULFATE	mg	3.65E+08	18451410	0	3.84E+08	0	3.84E+08	3.84E+08
SULFIDE	mg	1287.055	206.4246	0	2140.32	0	2140.32	2140.32
SULFUR	mg	85759.69	11679.12	0	131004.1	0	131004.1	131004.1
SUSPENDED SOLIDS, UNSPECIFIED	mg	9.96E+08	57388356	0	1.09E+09	0	1.09E+09	1.09E+09
TAR	mg	0.000181	9.07E-06	0	0.00019	0	0.00019	0.00019
TETRADECANE	mg	680.8655	101.6622	0	1089.604	0	1089.604	1089.604
THALLIUM	µg	708794.6	67985.83	0	924882.7	0	924882.7	924882.7
TIN	mg	7221.997	983.5841	0	11036.12	0	11036.12	11036.12
TITANIUM, ION	mg	131852.1	8964.584	0	151610.5	0	151610.5	151610.5
TOLUENE	mg	51683.13	7005.654	0	78768.06	0	78768.06	78768.06
VANADIUM	mg	27927.12	1472.109	0	29743.25	0	29743.25	29743.25
XYLENE	mg	24290.59	3498.022	0	38184.43	0	38184.43	38184.43
YTTRIUM	mg	189.3024	28.2655	0	302.9458	0	302.9458	302.9458
ZINC	mg	626761.1	37068.65	-10608	689761	-10608	689761	679153.1

Emissions To Land Life Cycle Inventory Results Table By Life Cycle Stages (A to D)

		PRODUCT (A1 to A3)			CONSTRUCTION PROCESS (A4 & A5)			END OF LIFE (C1 to C4)			BEYOND BUILDING LIFE (D)			TOTAL EFFECTS	
Emission	**Unit**	Manufacturing	Transport	**Total**	Construction-Installation Process	Transport	**Total**	De-construction, Demolition, Disposal & Waste Processing	Transport	**Total**	BBL Material	BBL Transport	**Total**	**A to C**	**A to D**
Other Solid Waste	kg	2.25E+03	3.17E+01	2.29E+03	1.12E+02	2.93E+01	1.42E+02	7.98E+01	3.50E+01	1.15E+02	0.00E+00	0.00E+00	0.00E+00	2.54E+03	**2.54E+03**
Solid Waste to Landfill	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.79E+05	0.00E+00	3.79E+05	0.00E+00	0.00E+00	0.00E+00	3.79E+05	**3.79E+05**
Steel Waste	kg	1.47E+00	0.00E+00	1.47E+00	7.33E-02	0.00E+00	7.33E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.54E+00	**1.54E+00**