REPUBLIC OF TÜRKİYE

ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Civil Engineering

COMPARISON OF BUILDING COST FOR THREE TYPES OF REINFORCED CONCRETE FLOORS IN HIGH-RISE BUILDINGS

Mane Abdourahman IBRAHIM

Master's Thesis

Supervisor

Prof. Dr. Zeki HASGÜR

Istanbul, 2022

COMPARISON OF BUILDING COST FOR THREE TYPES OF REINFORCED CONCRETE FLOORS IN HIGH-RISE BUILDINGS

Mane Abdourahman IBRAHIM

Civil Engineering

Master's Thesis

ALTINBAŞ UNIVERSITY

2022

The thesis titled COMPARISON OF BUILDING COST FOR THREE TYPES OF REINFORCED CONCRETE FLOORS IN HIGH-RISE BUILDINGS prepared by IBRAHIM MANE and submitted on 12/12/2022 has been **accepted unanimously** Of Master o fScience in Civil Engineering.

Prof. Dr. Zeki HASGÜR

Supervisor

Thesis Defense Jury Members:

Prof. Dr. Zeki HASGÜR
Department of Engineering and Architecture,
Altinbas University

Prof. Dr. Tuncer ÇELIK
Department of Engineering and Architecture,
Altinbas University

Doç. Dr. Beyza Taskin
Department of Engineering and Architecture,
Istanbul Technical University

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mane Abdourahman IBRAHIM

Signature

ABSTRACT

COMPARISON OF BUILDING COST FOR THREE TYPES OF REINFORCED CONCRETE FLOORS IN HIGH-RISE BUILDINGS

IBRAHIM, Mane Abdourahman

M.Sc.,Civil Engineering, Altınbaş University

Supervisor: Prof. Dr. Zeki HASGÜR

Date: December /2022

Pages: 58

As the world population, density and urbanization are increasing day by day, the need to design and build high-rise buildings became inevitable. One of the challenges faced by engineers working on such a domain is the cost of these types of buildings due to the cost of construction materials. For reinforced moderate high-rise buildings, the main building material that cost most is the concrete; formwork and the reinforcement. This work concerned the comparison of the cost of three types of flooring (slab with beams, flat slab and ribbed slab) to get the total concrete quantity, formwork and steel rebar's of the buildings, then to compare the whole building costs, where the RC shear wall and the columns are kept constant. Three 15 story,RC residential Building were designed with structural software (ETABS) and Turkish earthquake code, with those types of slabs. The buildings are assumed to build in Djibouti and also in Istanbul to compare the economical floor type and also the construction cost of the two cities.

Keywords: Cost of Construction Materials, Different Type of Slabs, Reinforced Concrete, TurkishEarthquake Code, Building Costs.

TABLE OF CONTENTS

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

1. INTRODUCTION

1.1 PROBLEM STATEMENT

A 15-storey residence building with three types of slabs is designed in our project.The type's floors of slabs involved in our project are slab with beam, Flat slab and ribbed slab. This study is conducted using ETAP software to design a beam, column and a shear wall. Once the sections of the elements, the concrete and the reinforcements are dimensioned, the quantities of reinforcement and concrete are calculated with Microsoft excel and then the price of quantities will be put in place in order to be able to compare the different slabs that are used for this study. Finally, this is how the most economical slab will be determined.

1.2 AIM OF THE STUDY

In this research, a 15-storey building which must resist the lateral forces which comes from the wind and the earthquake is in question. It also consists of determining the building's price study by changing the building's slab three times. Each building is different from the other by its slab, which leads first to the fact that the quantities of reinforcement and concrete are different for each type. This difference in quantities leads to a difference in price. To answer the problem posed in this research, the prices of each building with the slab will be determined to then discover the most economical., where they are built in Djibouti (Capital city of Djibouti republic) and Istanbul (most populated city in Turkey).

1.3 IN GENERAL

Since the dawn of time, the man first built with rudimentary means through to the aptitude of certain then the construction evolved to lead today to complex techniques and implemented by teams of technicians using high-performance equipment. The engineer is mainly involved in engineering teams responsible for dealing with complex technical problems, particularly in invention, innovation, social commitment, economic constraints, time and quality of a project.

The work of an engineer varies from one position to another so much that he has varied tasks to accomplish. The engineer is also endowed in all that is creativity, initiative or manufacturing and respect for the environment and regulations. Population growth and development of technology are the main factors in the construction of tall building.

The possibilities of realizing high-rise building are linked to the strength of the materials, the mains of access and also the expertism of the man or the engineers. Innovation in construction is developing rapidly and industries have enormous resources to improve construction technology. Investments in building technology have increased by 100% in recent years. This innovative investment; Research shows that companies ranked as "digitally smart" outperform enterprises by 48% in revenue and 15% in net margin. There has never been such an exciting time in the construction industry. As the rate of acceleration continues to change, innovation will lead to more improvements and developments.

2. TALL BUILDINGS

2.1 HISTORY

A building is a covered structure that is intended for housing or any other type of services to protect materials and people from climatic effects. To give a brief overview of the meaning of a tall building, the latter is a multi-story building whose access depends on an elevator to facilitate the movement of material and human goods. No universal definition is given for tall buildings. The regulations of the countries of the world give their own definition for the tall building. For example, that of German defines tall building; all buildings with a height of 22m while the technical committee of ASHRAE (American society of heating, refrigerating and Air-conditioning Engineers).For high-rise building defines them as buildings over 91m/300ft.(The Sustainability of Tall Building Developments: A Conceptual Framework. Kheir Al-Kodmany, 5 January 2018).“Because of their enormous scale tall buildings demand extraordinary determination and endurance from many stakeholders including owners, developers, planners, architects, and engineers. They exert significant demand on infrastructure and transportation systems, and affect the historic fabric while reshaping the city’s skyline. They also influence the micro-environment by casting shadows and blocking views and sunlight. Tall buildings consume massive quantities of energy and require a high operational cost. For these reasons some critics have viewed tall buildings as an undesirable display of extreme form of technological surge intruding upon the existing built environment that matches the human scale, and hence, an “urban evil” that reduces the quality and way of urban life. In the wake of the collapse of the World Trade Center (WTC) towers in New York in September, 2001 some skeptics took a pessimistic view by calling skyscrapers “death traps” and hastily and unfairly predicted their demise.” (Tall Buildings and Urban Habitat of the 21st Century: A Global Perspective Mir M. Ali 1 and Kheir Al-Kodmany,28 September 2012).Since 1945, World War II, tall buildings have seen an improvement on development. The evolution of technology as well as the architectural designs keeps increasing decades after decades. The planning concept which serves to superimpose several floors in order to benefit from the space by enlarging the surface of the net plank compared to the gross floor has not changed. The complexity of the style of construction as well as the development of structures and techniques has no negative influence on the economic plan and on the limits of new construction. Towards the end of the 20th century, the world of construction progressed on the quality and the duration of many buildings, on the new styles of the facades and especially the appearance of the forms and vocabulary of allegorical architecture.

2.2 TYPES OF TALLBUILDING (CLASSIFICATION)

Tall buildings are found in almost every country today. Given the population growth and the movement of nomads to the city, there is a shortage of space in the city. This is why the field of construction knows new technologies and construction from where the engineers have the responsibility to face the challenges that the world knows day after day. In the design of buildings, it is essential to first determine the use of the building, of which the latter is an important factor in the safety and quality measures of the structure. Generally, buildings are classified according to their function of users they accommodate. Residential buildings are intended to be occupied for private occupancy either on a permanent basis or not. Housing can be single-family, mobile rows and apartments. Buildings for public use are made up of public, private and semi-public properties. They offer a technical public service but they are not accessible to the public. They focus on three functions including light utility uses, medium utility uses and heavy utility uses. This category of light utility uses concerns small gauges for telephone services, sewer and hydroelectric. The category of building for medium utility uses consists of all construction spaces for the purposes of depots, municipal garages, solid waste recovery, vehicle cemeteries, sludge, and septic tanks. Building for heavy utility uses are spaces for public use that lead to certain harmful impacts such as incinerators for waste disposal and regional sanitary landfill sites. Building for commercial and service uses are subdivided into several classes, in particular specific conditions or urban development plans, services for complementary uses, complex difficulties and installation problems. Some classes of these kinds of buildings are retail, personal and service trade Professionals where the concerned are the commercial buildings where the sale as well as the treatment of the products do not require a storage space and are done directly with the presence of the consumers. Such as food products, financial services, sports shops, notaries. There are also road trades, extensive trades, indoor and outdoor recreational trades, rental trades of warehouses, accommodation, restaurants and shopping centers.

2.3 GENERAL CONSTRUCTION INFORMATION FOR A HIGH-RISE BUILDING

The construction of buildings involves taking into account the town planning and construction rules enacted by the construction and housing code. These regulations must guarantee factors such as ensuring safety, minimizing thermal and acoustic effects, facilitating access for disabled people, maintaining hygiene and of course preventing disorders and pathologies.

The high height of tall buildings causes the vertical and wind loads to be greater compared to buildings with a lower height. Moreover, the height of the structure is a factor which determines the complexity of the work in question. The realization of a construction project of large buildings requires a location of 3km at most from a center of public rescue and firefighting services. The principles of seismic construction are also taken into account, relying on the fact that large buildings comply with the dimensioning standards of a code according to a given country. The combustible materials in each compartment are limited under the conditions set by the corresponding regulations. The occupants must be evacuated by at least two stairs per compartment. Carry appropriate provisions to prevent the passage of smoke from the affected compartment to other parts of the building.

3. LOADS

After having determined the recommendations requested by the section of the structural elements of the work, it will be necessary to go to the next step which is to know the loads that the work must withstand. During the design, the definition of the loads that the building is subjected will ensure its resistance. Live loads and dead loads of the structure are determined first face then the large horizontal loads from wind and earthquakes must be taken into account for the protection of the qualities. For this we set up the shear wall.The designer or the engineer specialized in the structural field refers to the two types of code specified such as the minimum standards construction code in order to know the loads that the building must support. The requirements of the structural designs are given by the designer with clear techniques Kassimali [4].

3.1 DEAD LOADS

Dead loads concern the weight of all structural elements. The weight of each element of the structure remains unchanged and permanent throughout the life of the building. The dead load of a building is the sum of all the weights of the main component of the structure such as beams, columns, slabs, roofing, and windows. Structural dead load is determined by simple formulas depending on the size and weight of similar structure. By experience one can assume the weight of a structural member. The structural dead load is calculated by simple formulas in relation to the size and weight of an equivalent structure. The weights of non-load-bearing elements must also be taken into account.

3.2 LIVE LOAD

The live loads correspond relatively to the mobile overloads to which the building is subjected. These loads are increased by the verification of the constraints (for example, a coefficient of 1'16 is required for increased according to the Turkish code).The values of operating costs depend on the areas to which they are applied, the horizontal or vertical digressions used related to the types of characteristics of the charges in question and how they are taken into account. All these dependent parameters must be processed. The latter are used taking into account, on the one hand, reductions or digressions for large areas or plurality of floors, and on the other hand, possible unfavorable conditions of their distribution.

3.3 WIND LOADS

The wind is a natural and variable action over time on an element located outside. The wind load is considered as a variable free action. Furthermore, the load can be combined with other actions (for example, imposed load or snow) in design situations defined according to the standard in 1990. Changes of the dynamic coefficients due to other actions (snow, traffic or ice) and due to structural changes must be considered during construction. The buildings undergo the movements of the wind. The conversion of kinetic energy into pressure potential energy creates the wind load. Air density, air shape and velocity, wind incidence angle, building size and stiffness, and structural surface roughness are the main factors influencing the strength of the wind on the surfaces of a structure. The variable pressure due to permanent wind action is estimated by an average velocity pressure that the structure receives. Pressure is determined by kinetic energy Hibbeler [5].

$$Q=\frac{1}{2}r v^2 \tag{3.3. 1}$$

With:

r= specific mass of air

v= wind speed

For a closed structure, the choice to design the wind pressure is related to the height and the flexibility of the building noting well also in the conditions of a system resistant to the actions of the wind is designed. Having the shape and location of a structure with a high height, it is essential to take as a reference a dynamic approach in order to determine the wind pressure. It is according to the usefulness of the work and the position of the land as well as the height of the structure that the standard design code gives the basic adjustment formulas. For tall buildings or structures whose shape or location is sensitive to wind, it is recommended to use a dynamic approach to define wind loads. The techniques used are mentioned in several design standards, the tests are studied on a type of building in order to activate the natural environment. The consequences of the action of the wind on the structure can be specified with pressure sensors hooked to the model whose characteristics of rigidity and the scale is appropriate to the work the dynamic deviations can be defined [10].

3.4 EARTHQUAKE EFFECT ON HIGH-RISE BUILDINGS

3.4.1 Definition

Earthquake is a sudden and momentary jolt or vibration of the earth's crust. The geologists claim that it is a phenomenon that dates back a very long time, to be seen even before the existence of man. This phenomenon was considered supernatural until it was discovered to be a completely natural phenomenon in the mid-17th century [6].This event causes material and human damage. The earthquake can be the result of a phenomenon that has natural or artificial origins. Earthquakes of tectonic origin: these are the most common and most devastating earthquakes induced by the agitation of tectonic plates. The elastic limit of the lithosphere reaches its maximum once its rocks undergo pressure from the friction of the two tectonic plates. Then the lithosphere releases the stored energy from which the earthquake manifests. The separation and collision of two plates can cause an earthquake.

Volcanic earthquakes: the warning signs of volcanic eruptions that are caused by the buildup of magma in a volcano. These earthquakes are less risky compared to those of tectonic origin. Earthquakes of artificial origin: certain human activities that disturb the integrity of the lithosphere are reasons for this type of earthquake. The impoundment of a large dam, the exploitation of gas, the seismic exploration shots, the shots of mines and quarries, the underground nuclear tests and the collapse of old mines are examples of earthquakes caused by the 'human activity.

3.4.2 The Effect of the Earthquake

The earthquake negatively infects human life, buildings and road structures, the environment and also the economy. The earthquake is considered one of the deadliest natural disasters. Earthquakes are almost unexpected and particularly damaging due to their devastating consequences. Earthquakes cause significant damage and often claim many victims in accordance with their intensity and locality. The population's supply of basic necessities is collapsing. Buildings, crops, livestock and drinking water sources are destroyed.

4. LITERATURE REVIEW

Structures have a primordial place in the economic development of an entire country. This leads to high cost when not analyzed and designed properly. For this, it is important to have an appropriate analysis and design system to find an economical and quality structure. The financial management of a construction project, whatever its size has always been important to define it well. In all the phases of the realization of a structure, the estimate is made. According to many studies that specialists in the field of civil engineering, it has been approved that the type of slab used has an impact on the cost of a project. The world of construction is developing and using new techniques. This has coated a novelty in the field of construction. The cost of a project is at the moment a major factor for the competition of the big companies of construction. There are a good number of various slab systems that respect the load and span provisions while being economical. However, the good choice of floor type is necessary. A study project of a building was carried out by Rajashekar, Chandrashekar andKrishna in 2015.They brought validated and watchful resolutions on the last phase of the design which must be used in the sense that it is considered in its period of life[7].In defiance of the natural disaster, in particular the earthquake which affects the buildings, the areas of construction continue the evolution of the large buildings with a discontinuous rigidity. There is a risk on the subject of large current buildings compared to the old ones. The solutions to cure these defects can be one, the improvement of structural system, the use of shear walls and a care of property of building materials. Placing shear walls parallel to the directions that the lateral forces originate can provide resistance to wind and earthquake effects. This study basically consists of a comparison of bills of quantities and estimates in order to deduce which of the floors cost less while ensuring the stability of the building.

4.1 ETABS SOFTWARE

ETABS is software for engineers to model and design the structural analysis and design calculations of buildings with high height. It was in 1963 that the idea of putting this software was put in place then it was realized in 1984. This software has several versions in order to improve and make it more recent and modern. This latest version offers modeling and visualization support on 3D objects.

It has a capacity for delicate and accomplished designs, a wide range of materials, lively and clear graphic displays, summary reports, and easily readable diagrams to give analysis and design results to engineers or anyone else who may use it. CAD drawings can be imported into ETABS. Analyzing such a large and complex project determines the effectiveness of this software [7].

5. CASE STUDIES: DESIGN OF A MODERATE HIGH-RISE RCBUILDINGS

5.1 BUILDING GENERAL INFORMATION

In this work, a 15-storey RC residential building was designed with three types of floors (Slab with beam- Flat slab - Ribbed slab) and in this research, ETABS program was used to design a shear wall, column and beam after applying a Lateral force (winds and earthquakes) on the building. This building is 21.9m long, 11.5m wide and 46m height, with ground floor and 14 ordinary stories. The ground floor is 4m where all the other stories are 3m height. The building is assumed to build in Djibouti (capital city of Djibouti republic) and in Istanbul, the soil type is taken as ZB in Istanbul and zone-1 regarding the earthquake seismic hazard. The building is designed according to Turkish earthquake code. The building usage classification factor (BKS) is 3 and as the building is residential building, an Importance factor (I) is 1. All the frames are casted in place, designed to resist all seismic loads and assumed as high ductile system so seismic load reduction factor and structural behavior factor became equal (R_a= R = 8). With 5% damping, the sum participating of mass factor must be greater than 0.95 and the sum of twelve modes the total mass participation factor is 0.9601 in X-direction and 0.9519 in Y-direction which are greater than the limit. The slabs are considered as rigid diaphragm and after designing all the structural sections, the rebar and concrete quantities and formwork were calculated in Microsoft Excel, and these quantities were compared according to a building with a slab with beams, a building with flat slab and a building with ribbed slab. The quantities are then priced in order to know which type of floors economical compared with the other two floors.

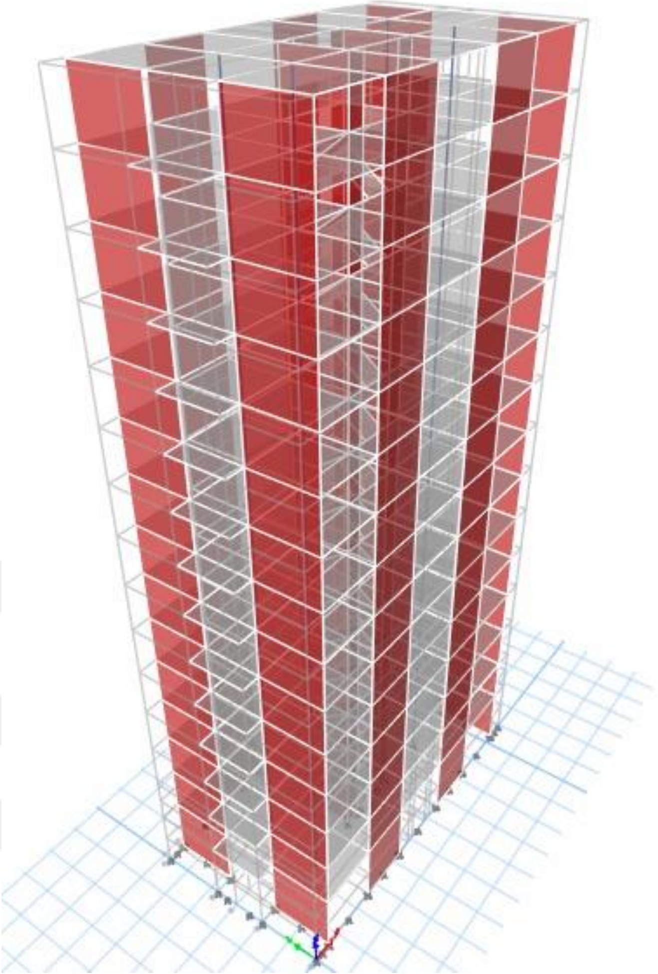


Figure 5.1: 3D view.

5.1.1 Story Data and Mass Participation Factor

Table 5.1: Story Data.

Name	Height mm	Elevation mm	Master Story	Similar To	Splice Story
Story15	3000	46000	Yes	None	No
Story14	3000	43000	No	Story15	No
Story13	3000	40000	No	Story15	No
Story12	3000	37000	No	Story15	No
Story11	3000	34000	No	Story15	No
Story10	3000	31000	No	Story15	No
Story9	3000	28000	No	Story15	No
Story8	3000	25000	No	Story15	No
Story7	3000	22000	No	Story15	No
Story6	3000	19000	No	Story15	No
Story5	3000	16000	No	Story15	No
Story4	3000	13000	No	Story15	No
Story3	3000	10000	No	Story15	No
Story2	3000	7000	No	Story15	No
Story1	4000	4000	No	Story15	No
Base	0	0	No	None	No

Table 5.2: Modal Participating Mass Ratios.

Case	Mode	Period (sec)	UX	UY	Sum UX	Sum UY
Modal	1	1.154	1.17E-05	0.7034	1.171E-05	0.7034
Modal	2	1.091	0.729	1.14E-05	0.7290117	0.7034114
Modal	3	0.823	4.29E-06	0	0.729016	0.7034114
Modal	4	00.309	0.1271	9.52E-07	0.856116	0.7034123
Modal	5	0.3	1.10E-06	0.1461	0.8561171	0.8495123
Modal	6	0.214	0	0	0.8561171	0.8495123
Modal	7	0.146	5.51E-02	0	0.9112171	0.8495123
Modal	8	0.132	0	0.0602	0.9112171	0.9097123
Modal	9	0.093	0	0	0.9112171	0.9097123
Modal	10	0.084	0.0305	0	0.9417171	0.9097123
Modal	11	0.074	0	0.0322	0.9417171	0.9419123
Modal	12	0.056	0.0184	0.01	**0.9601**	**0.9519**

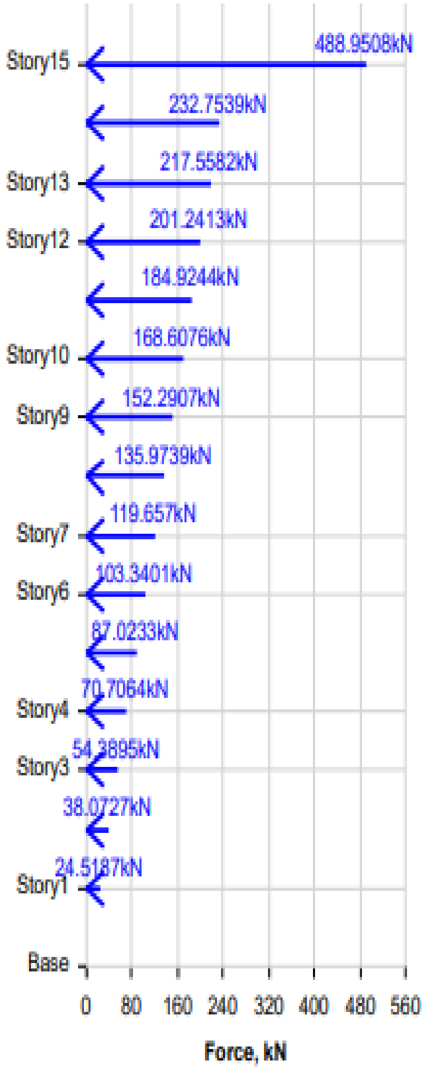
5.1.2 Material Properties and Loads

Table 5.3: Material used and Forces.

	Normal stories	Top Floor	Materials
Dead (KN)	1.5		
Live (KN)	3	2	
	Concrete		C30
	Steel Rebars		S420

5.1.3 Lateral Force

Table 5.4: Lateral forces.



Story	Elevation m	X-Dir kN	Y-Dir kN
Story15	46	488.9508	0
Story14	43	232.7539	0
Story13	40	217.5582	0
Story12	37	201.2413	0
Story11	34	184.9244	0
Story10	31	168.6076	0
Story9	28	152.2907	0
Story8	25	135.9739	0
Story7	22	119.657	0
Story6	19	103.3401	0
Story5	16	87.0233	0
Story4	13	70.7064	0
Story3	10	54.3895	0
Story2	7	38.0727	0
Story1	4	24.5187	0
Base	0	0	0

5.1.4 Structure Analysis

Table 5.5: Centers of Mass and Rigidity.

Story	Diaphragm	Mass X (kg)	Mass Y (kg)	XCM (m)	YCM (m)	Cumulative Y (kg)	XCCM (m)	YCCM (m)
15	D1	157230.8	157230.8	10.95	5.75	157230.76	10.95	5.75
14	D1	169760	169760	10.9489	5.7596	326990.77	10.9494	5.755
13	D1	170916.4	170916.4	10.9487	5.769	497907.18	10.9492	5.7598
12	D1	170916.4	170916.4	10.9487	5.769	668823.58	10.9491	5.7621
11	D1	170916.4	170916.4	10.9487	5.769	839739.99	10.949	5.7635
10	D1	170916.4	170916.4	10.9487	5.769	1010656.4	10.949	5.7644
9	D1	170916.4	170916.4	10.9487	5.769	1181572.81	10.9489	5.7651
8	D1	170916.4	170916.4	10.9487	5.769	1352489.21	10.9489	5.7656
7	D1	170916.4	170916.4	10.9487	5.769	1523405.62	10.9489	5.766
6	D1	170916.4	170916.4	10.9487	5.769	1694322.03	10.9489	5.7663
5	D1	170916.4	170916.4	10.9487	5.769	1865238.44	10.9489	5.7665
4	D1	170916.4	170916.4	10.9487	5.769	2036154.84	10.9488	5.7667
3	D1	170916.4	170916.4	10.9487	5.769	2207071.25	10.9488	5.7669
2	D1	170916.4	170916.4	10.9487	5.769	2377987.66	10.9488	5.7671
1	D1	174477.8	174477.8	10.9488	5.7687	2552465.46	10.9488	5.7672

Table 5.6: Base reactions.

Load Case/Combo	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
Dead	-957.2963	0	5369.3235	30689.8987	-81463.6315	5504.454
Live	0	0	10314.7058	59260.0917	-112566	8.124E-07
EQX	-2280.0085	0	0	5.862E-07	-74632.7215	13132.6992
EQY	0	-2179.1612	0	71331.6343	-1.463E-06	-23842.302

5.2 STRUCTURE DESIGN OF RC ELEMENTS

5.2.1 Shear Wall

5.2.1.1 Definition

The shear wall can be construction in several ways and with different materials. Shear walls are vertical elements of a system consisting of reinforced concrete walls designed to provide resistance against the horizontal forces of natural phenomena and the lateral rigidity of the structure. Buildings with many stories require the shear wall. Axial and design bending stresses lead to shear and bending strains. The shear walls are built on site by casting or they are precast when they are in reinforced concrete [10]. The stiffness of a shear wall is towards its major axis relative to the other axis. It is also considered as the primary structural element that receives and resists all the efforts of the two senses that act on its plane. Masonry shear walls are used with solid walls and cast cavity masonry to support shears and moments. A distribution of internal stresses is the result of the creation of axial shear and bending forces by a shear wall. The charges it receives are transferred to the foundation. The geometry, the property components of the materials and the stresses remain parameters which play an important role in the definition of the attenuation of the element. In these buildings, concrete shear wall is used at the center of the building as core shear wall and exterior as boundary shear wall with 35cm thickness. The shear walls are extended throughout of the building, so the height of the shear wall (H_W) is 46m. According to Turkish Code, high ductility shear walls must have at least 20cm thickness which is verified with our condition (35cm) and the longest shear wall in this building (L_W)is 400cmH_W/L_W = 11.5 which is greater than 2 so the wall end-zones are needed. The end-zones are at the ends of each shear wall and their length are 20% of the maximum shear wall length, L_u= 0.2x400 = 80cm. H_{CR} the critical shear wall height should not exceed $2L_W$ and should exceed the maximum length L_W (400cm), for this building the critical wall height is taken 600cm ($H_{CR} = 6m$).

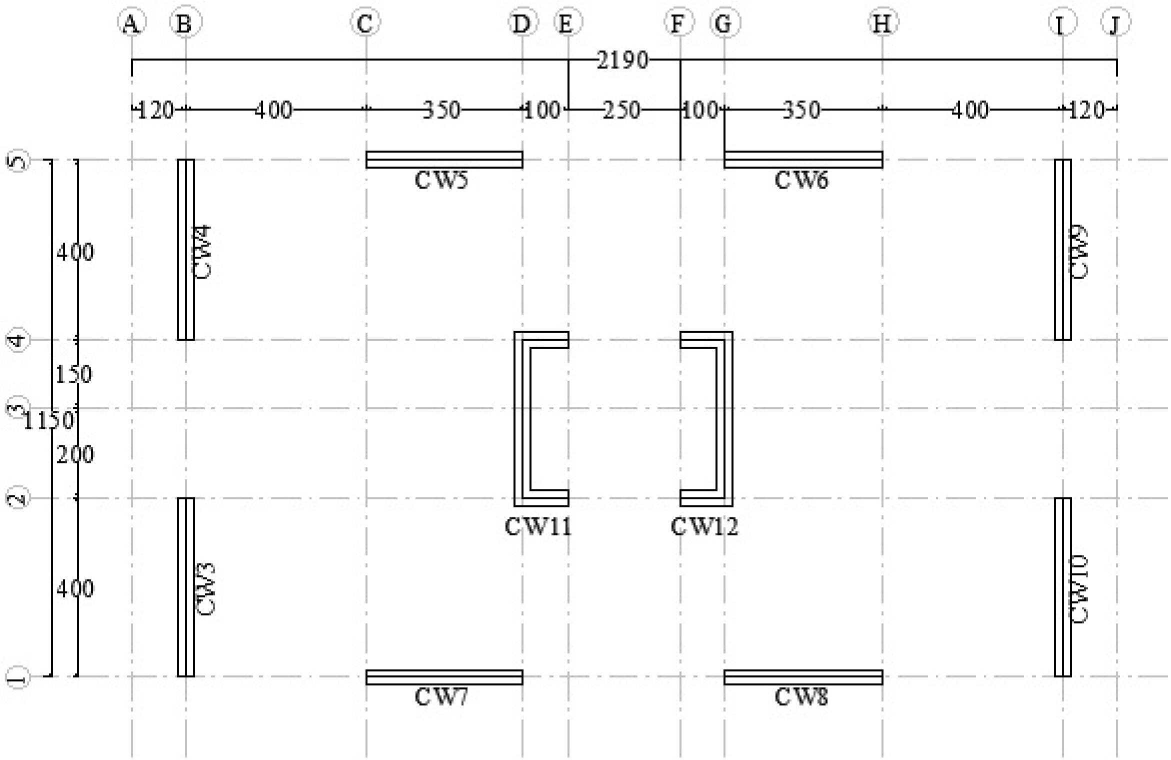


Figure 5.2: Shear wall layout.

5.2.1.2 Flexural design for shear wall (1) story (1) with width of 4m.

Table 5.7: Flexural Design Pu, Mu2 and Mu3.

Station Location	**Required Rebar Area (mm^2)**	**Required Reinf Ratio**	**Current Reinf Ratio**	**Flexural Combo**	**N_d kN**	**M_{d2} kN-m**	**M_{d3} kN-m**	**Pier A_g mm^2**
Top	14000	0.0025	0.0031	DWalS18	11378.253	-1082.657	-37417.834	5600000
Bottom	14000	0.0025	0.0031	DWalS18	11882.104	-1085.852	-44064.996	5600000

5.2.1.3 Shear design

Table 5.8: Shear Design.

Station Location	ID	Rebar mm²/m	Shear Combo	N_d kN	M_d kN-m	V_d kN	V_c kN	V_w kN	V_r kN	V_u kN
Top	Leg 1	875	DWalS4	4836.9	-5196.9	430.1	1444.2	1007.2	2451.5	6160
Bottom	Leg 1	875	DWalS4	4976.905	-6919.1	431.0	1452.4	1007.2	2459.6	6160

5.2.1.4 Reinforcement detailing for shear wall

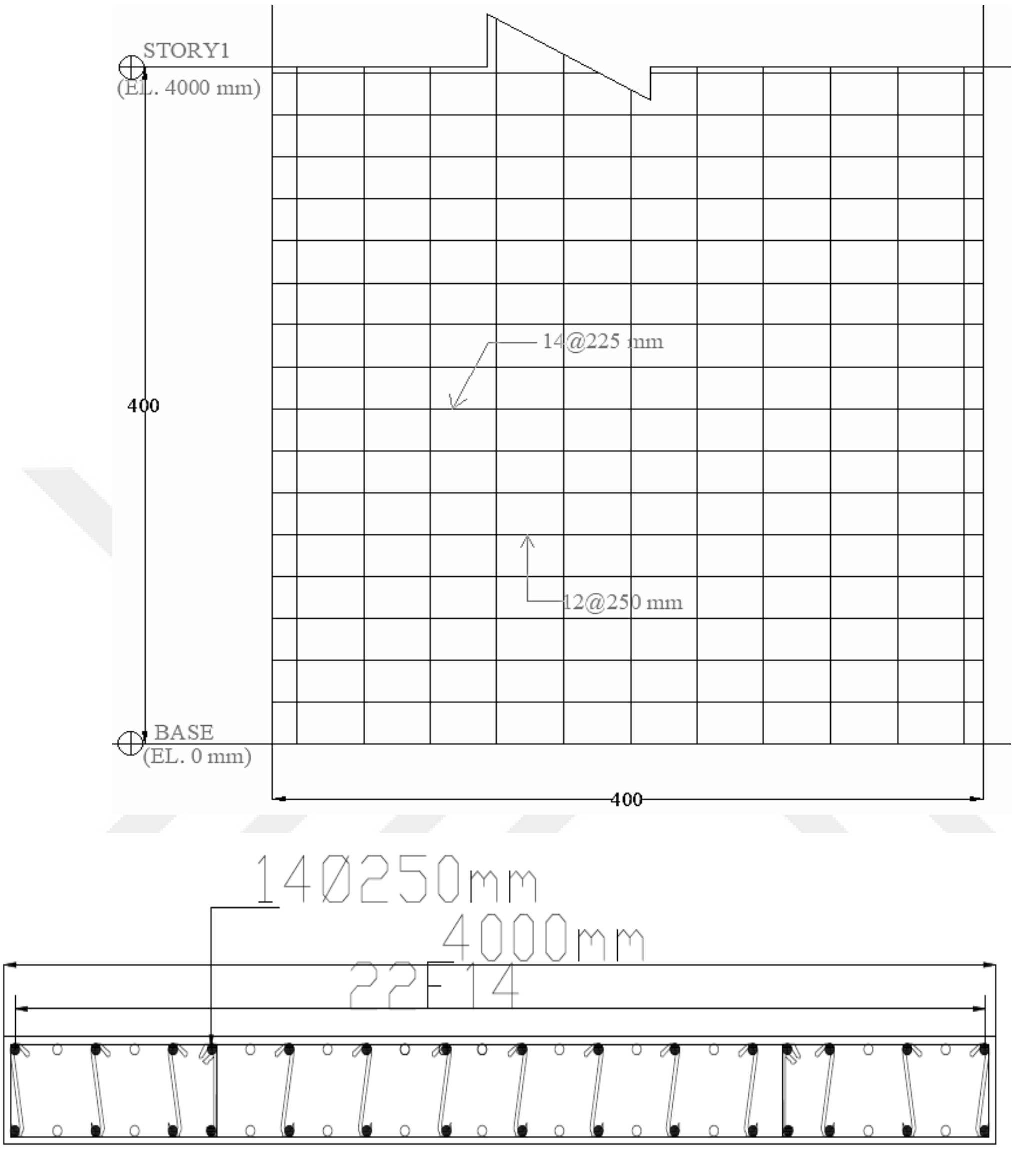


Figure 5.3: Reinforcement Detailing for 4m Shear Wall.

5.2.2 Core Shear Wall

5.2.2.1 Flexural design for P_u, M_{u2} and M_{u3}

Table 5.9: Flexural Design Pu, Mu2 and Mu3.

Station Location	Required Rebar Area (mm²)	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	N_d kN	M_{d2} kN-m	M_{d3} kN-m	Pier A_g mm²
Top	9625	0.0025	0.0078	DWalS20	480.9247	-8.6425	475.0296	3850000
Bottom	9625	0.0025	0.0078	DWalS20	740.7229	-14.9596	519.1789	3850000

5.2.2.2 Shear design

Table 5.10: Shear Design.

Station Location	ID	Rebar mm²/m	Shear Combo	N_d kN	M_d kN-m	V_d kN	V_c kN	V_w kN	V_r kN	V_u kN
Top	Leg 1	875	DWalS16	189.233	62.2422	85.852	1028.627	881.33	1909.9567	5390
Bottom	Leg 1	875	DWalS16	322.587	111.6773	43.191	1036.381	881.33	1917.7112	5390

5.2.2.3 Reinforcement detailing for core shear wall

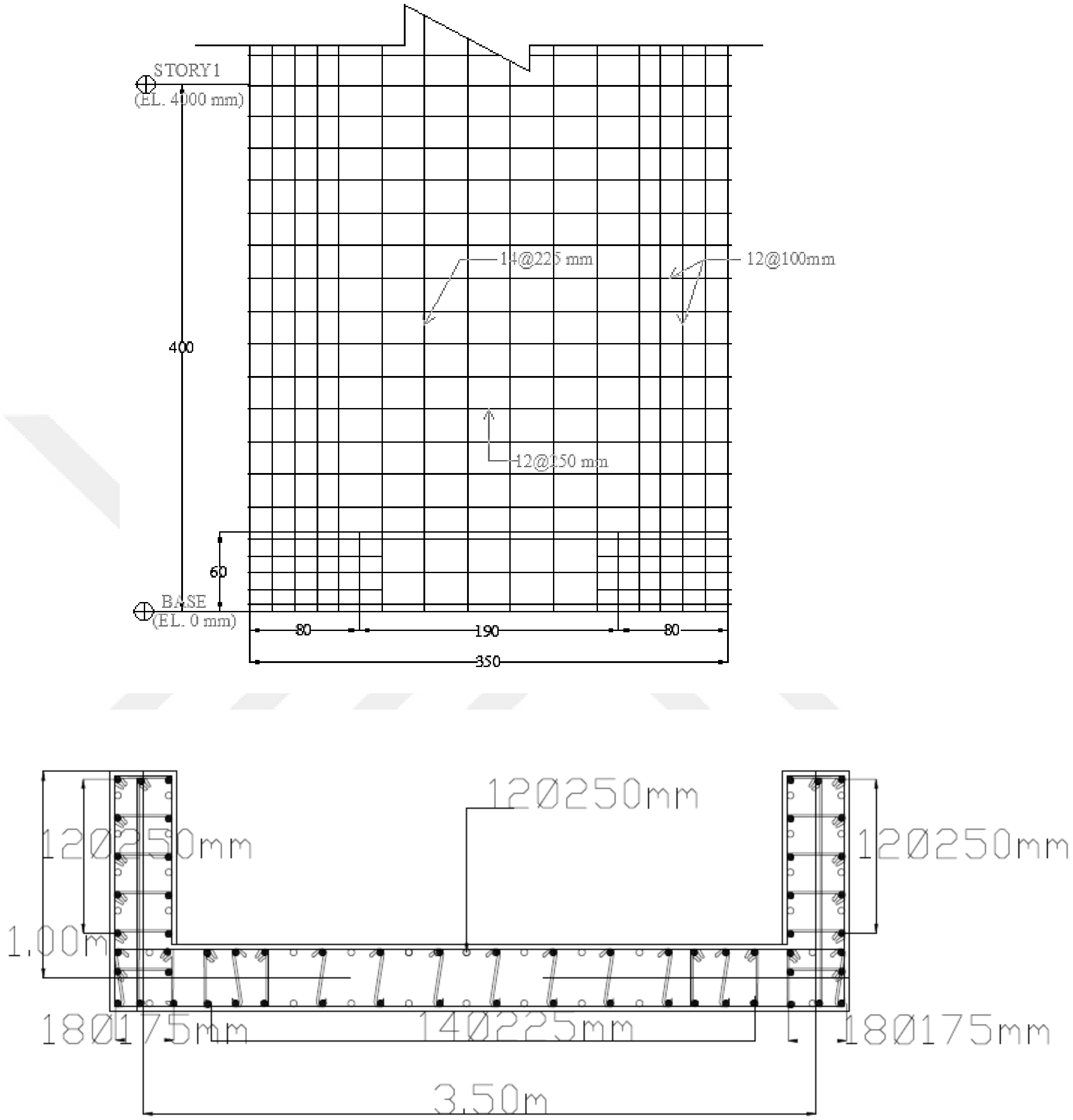


Figure 5.4: Reinforcement Detailing for Core Shear Wall.

5.2.3 Column

5.2.3.1 Definition

Columns are the vertical elements subjected to the compression of which it must ensure its rigidity of resistance. They receive the loads from the slab and beam and then in turn transfer them to the foundations. Axial compression the cross section of the pipe and wide flange is usually steel column, rectangular, square and round columns are usually reinforced concrete Kassimali [4]. According to the code that we used for this building, the rectangular column cross section must be greater $750cm^2$with the minimum allowable dimension is 25cm, and the longitudinal reinforcement ratio in the high ductile column should be at least 0.01 and 0.04 at maximum. For rectangular sections, we are not allowed to use less than Ø14, and for circular cross-sectional columns, less than six rebar are not allowed. For stirrup and tie spacing should be at minimum of 1/3 of the small column dimension or greater than 10cm, and their diameter mustn't be less than Ø8.

In these structures, we have only 4 columns with the same dimensions (50cmx70cm) that go throughout the building. The following figure shows the column lay out.

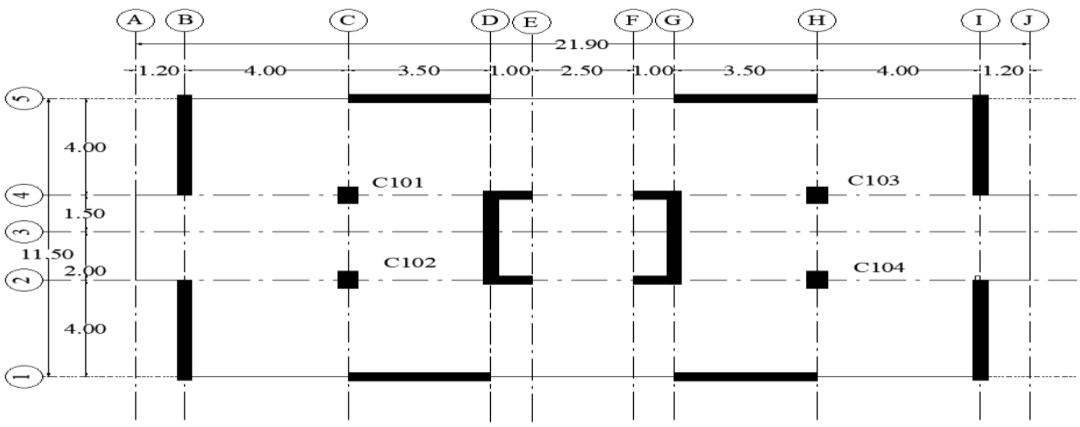


Figure 5.5: Column Lay-out.

The column that I choose to design as an example is located at the 13th story of building and axis 2-H with the name of C1304.

5.2.3.2 Flexural design for column (C1304) story (13)

Table 5.11: Axial Force and Biaxial Moment Design for Nd, M d2, M d3.

Design N_d kN	Design M_{d2} kN-m	Design M_{d3} kN-m	Minimum M2 kN-m	Minimum M3 kN-m	Rebar Area mm^2	Rebar % %
11.5215	33.1615	1.3846	0.3456	0.4148	3500	1

5.2.3.3 Shear design

Table 5.12: Shear Design for V d2, V d3.

	Shear V_d kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_v/s mm^2/m
Major, V_{d2}	83.2441	0	122.6902	83.2441	532.91
Minor, V_{d3}	83.2441	0	118.0895	83.2441	746.08

The longitudinal reinforcement ratio of the column that I selected is $\boldsymbol{\rho_{min}} = \frac{\mathbf{3500}}{\mathbf{500x700}} = 0.01$ which is equal to the minimum ratio according to the code and of course smaller than 0.04.

5.2.3.4 Reinforcement detailing for column (C1304) story (13)

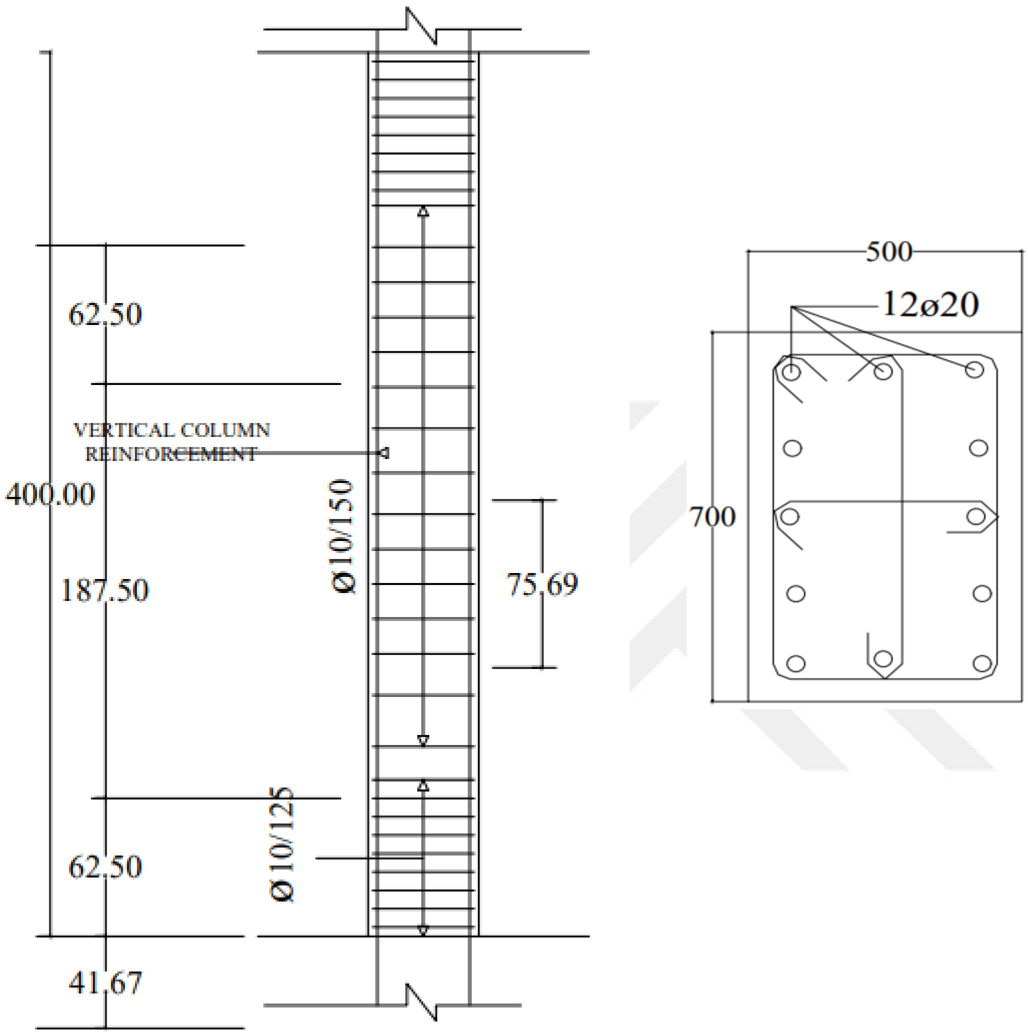


Figure 5.6: Reinforcement Detailing for Column.

5.2.4 Beams

5.2.4.1 Definition

Beams are the horizontal load-bearing elements which are among the framework of a floor and which are subjected to mechanical actions such as bending, torsion as well as the moment that these generate. These support elements must face to never get tired of breaking after an application of forces and moments. It also ensures the transfer of loads coming from the slab and going towards the column Kassimali[4]. According to Turkish Code, ductile reinforced concrete beams must have three times the slab thickness, 25cm width at least and a height of three times it's width at least. In these structures, three types of ductile reinforced concrete beams are used and their sections are summarized in the table below.

Table 5.13: Beam dimensions.

Beams	Width (cm)	Depth(cm)
External(couple Beams)	25	80
Internal	30	60
Hidden beams	70	35

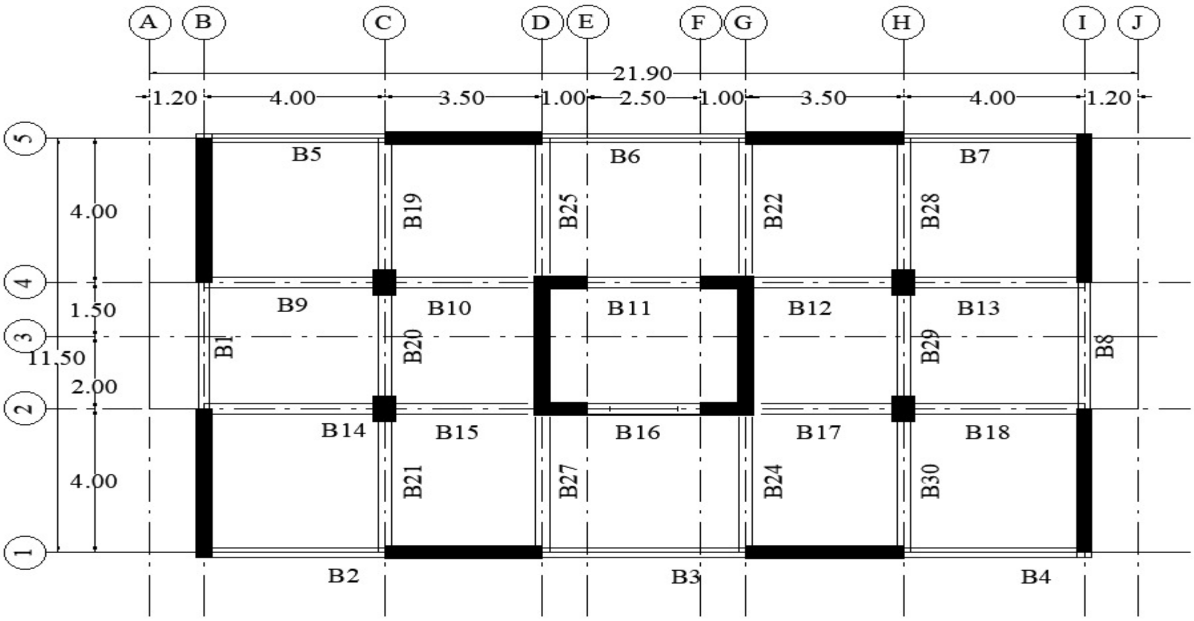


Figure 5.7: Beam layout.

Due to the number of pages that it would take if I present all the details of the beams, I selected to design as an example three different beams, one from each group.

One beam from external, one from internal and one from hidden beams.

5.2.4.2 Internalbeam: 30*60

Design moment and flexural reinforcement for moment

Table 5.14: Design Moment and Flexural Reinforcement for Moment Mu3.

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm^2	+Moment Rebar mm^2	Minimum Rebar mm^2	Required Rebar mm^2
Top (+2 Axis)	-1.882		10	0	460	460
Bottom (-2 Axis)		0.941	0	5	460	460

Shear force

Table 5.15: Shear force and reinforcement for shear Vu2.

Shear V_{d2} kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_v/S mm^2/m
86.1146	0	62.1117	86.1146	319.75

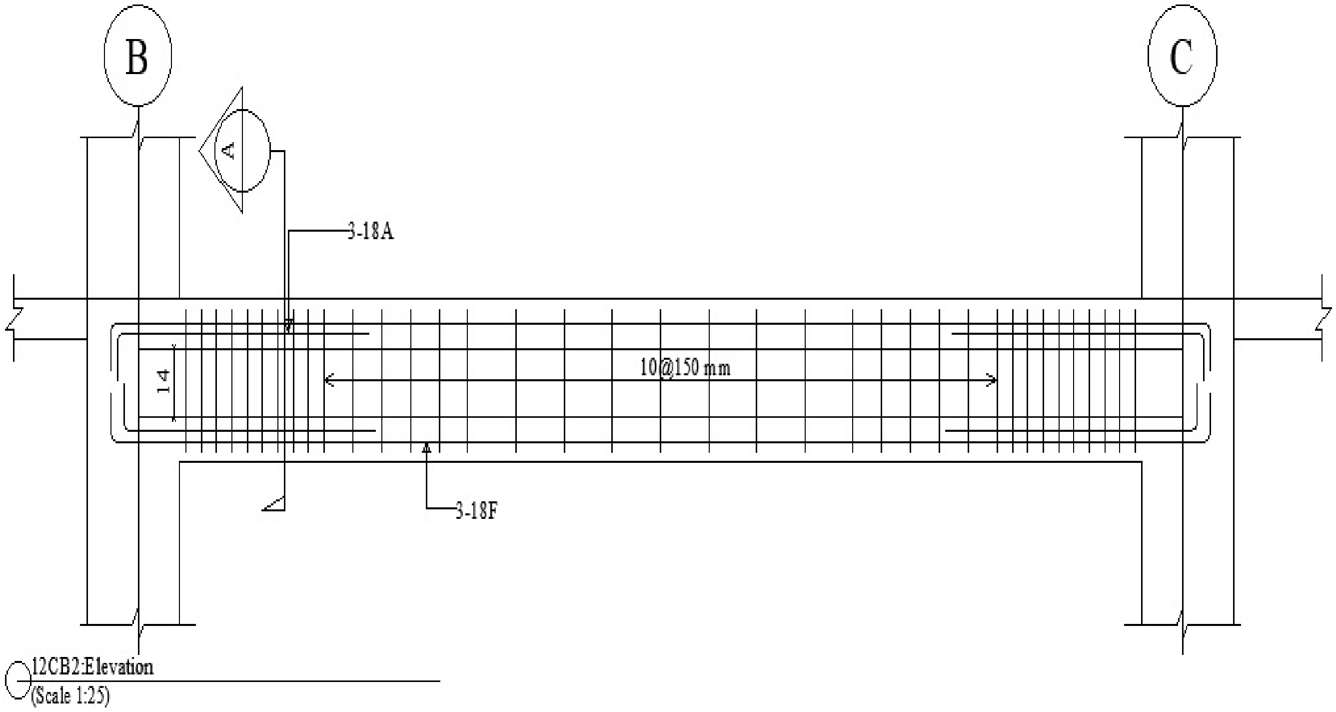
Torsion force

Table 5.16: Torsion force Tu.

T_d kN-m	Tcr kN-m	Area A_e cm^2	Perimeter, u_e mm
0,0674	14,9528	1101,6	1560

The longitudinal reinforcement ratio of these beams is $\rho = \frac{460}{300x600}$ = 0.002556 and the minimum $\rho_{min} = \frac{0.8x1.25}{365}$ = 0.0027 which is smaller thanthe calculated ratio. OK

Reinforcement detailing



Internal Beam elevation

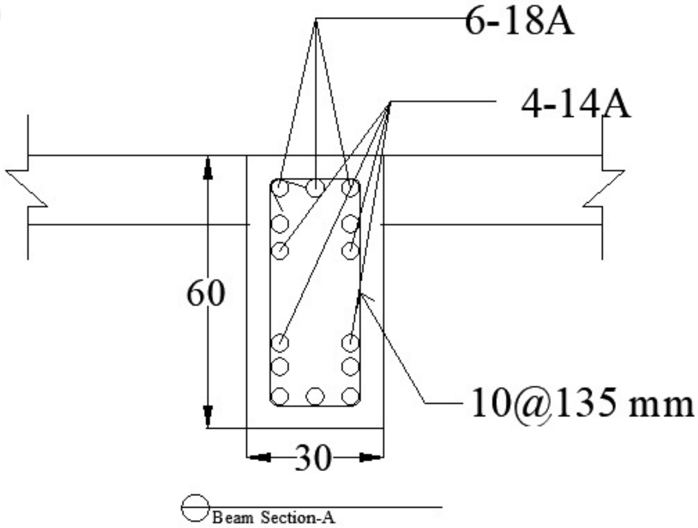


Figure 5.8: Internal Beam Reinforcement Detailing.

5.2.4.3 External beams: 25x80

Design moment and flexural reinforcement for moment

Table 5.17: Design Moment and Flexural Reinforcement for Moment Mu3.

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	0		0	0	0	0
Bottom (-2 Axis)		34,2132	0	129	526	526

Shear force

Table 5.18: Shear force and reinforcement for shear Vu2.

Shear V_{d2} kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_v/S mm²/m
97,7033	0	70,9301	97,7033	266,46

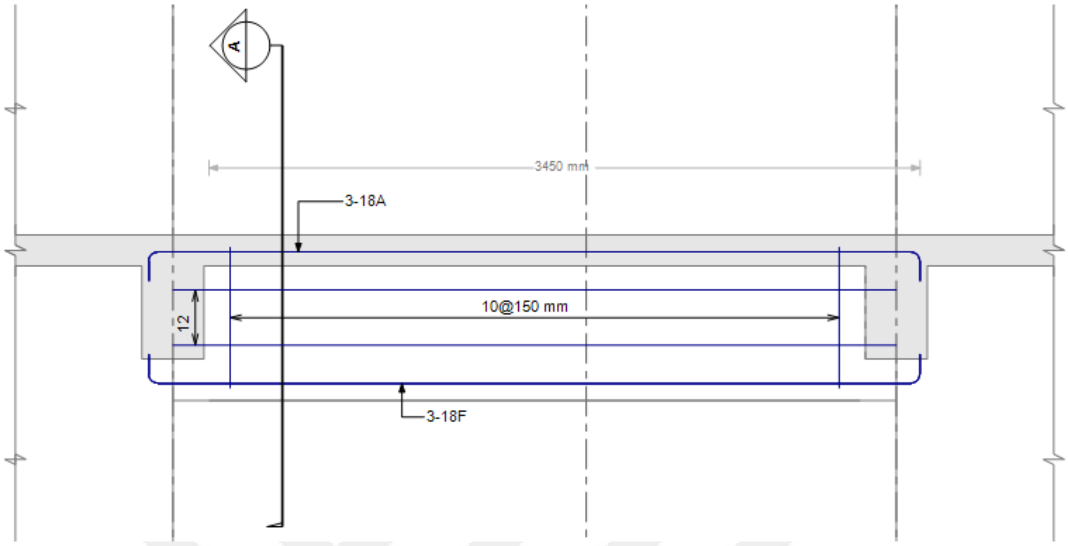
Torsion force

Table 5.19: Torsion force Tu.

T_d kN-m	Tcr kN-m	Area A_e cm²	Perimeter, u_e mm
0,2064	13,8452	1195,1	1860

The longitudinal reinforcement ratio of these beams is $\rho = \frac{\mathbf{526}}{\mathbf{250x60}}$ = 0.0035 and the minimum $\boldsymbol{\rho_{min}} = \frac{0.8x1.25}{365}$ = 0.0027 which is smaller than the calculated ratio. Ok

Reinforcement detailing for external beams



External Beam elevation

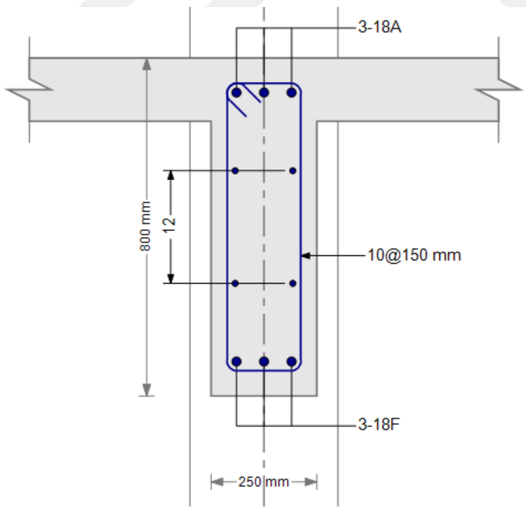


Figure 5.9: External Beam Reinforcement Detailing.

5.2.4.4 Hidden beam: 70x35

Design moment and flexural reinforcement for moment

Table 5.20: Design Moment and Flexural Reinforcement for Moment Mu3.

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	-5.763		55	0	577	577
Bottom (-2 Axis)		2.8815	0	28	577	577

Shear force

Table 5.21: Shear force Vu2.

Shear V_{d2} kN	Shear V_c kN	Shear V_s kN	Shear V_p kN
55.7657	134.9077	77.8314	44.2259

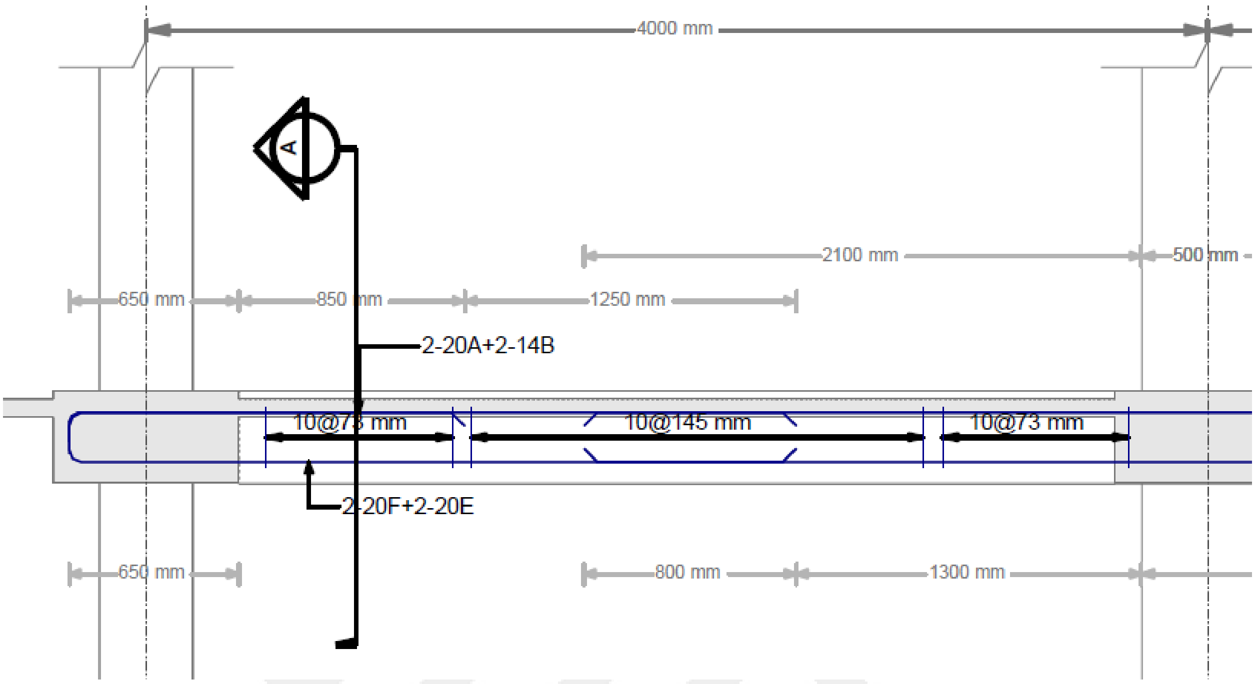
Torsion force

Table 5.22: Torsion force Tu.

T_d kN-m	Tcr kN-m	Area A_e cm²	Perimeter, u_e mm
0.5351	23.7445	1577.6	1860

The longitudinal reinforcement ratio of these beams is $\rho = \frac{\mathbf{577}}{\mathbf{350x60}}$ = 0.027 and the minimum $\rho_{min} = \frac{0.8x1.25}{365}$ = 0.0027 which is smaller than the calculated ratio. Ok

Reinforcement detailing for hidden beams



Hidden Beam Elevation

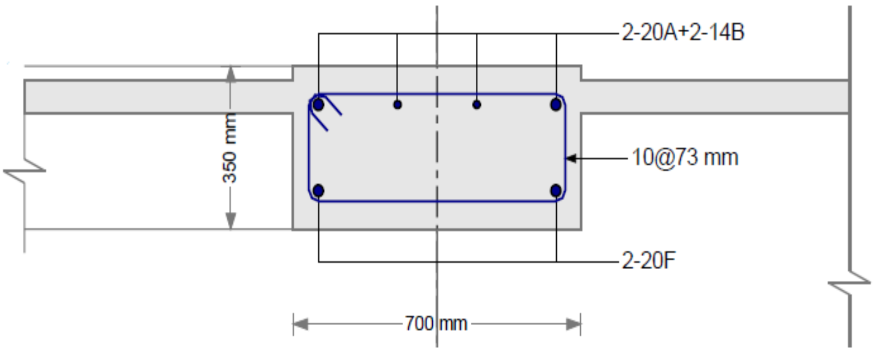


Figure 5.10: Hidden Beam Reinforcement.

5.2.5 Slabs

Slab is a horizontal load-bearing structure with a smaller thickness compared to its other dimensions. It can be reinforced or prestressed concrete. Slabs can be continuous support over one or more span directions and can also be cantilevered free at one end and held at the other end Kassimali [4]. In this structure, three different slab types are used, namely; flat slab, conventional slab (slab with beams) and ribbed slab. The slabs are designed then reinforcement details, maximum floor displacement and maximum inter-story drifts are presented.

5.2.5.1 Slab with beam

The floor in a slab-beam system is the beam and slab assembly. The beam has a high depth while the slab is thick. These types of slabs are supported by beams in all directions which are constructed monolithically with them. There are two types in this group; one-way slabs and two-way slabs. One-way slabs are where the ratio of the long length to the short is greater than 2 while when this ratio is less than 2 the slabs are called two-way slabs. The slab transmits the loads to the beams which will in turn transmit to the columns and finally the columns transfer to the foundations. In Turkish code the minimum slab thickness is 80 mm. In this building, I selected the slab with the largest sides (4.5m in the long span and 4m for the short span).

h≥ $\frac{L_{sn}}{15+\frac{20}{m}}\left(1-\frac{\alpha_s}{4}\right)$ or h≥ $80mm, L_{sn}=4.2m, m=1.125\ and\ \alpha_s=0.735,$

h≥ 105mm and I choose 150mm for this kind of slabs.

Table 5.23: Normal Slab Period.

Normal Slab					
Direction	Period Used (sec)	S(T 1)	W (kN)	V (kN)	F N (kN)
X	1.412	0.911516	34322.6633	1787.751	201.122
Y	1.45	0.892286	34322.6633	1750.036	196.879

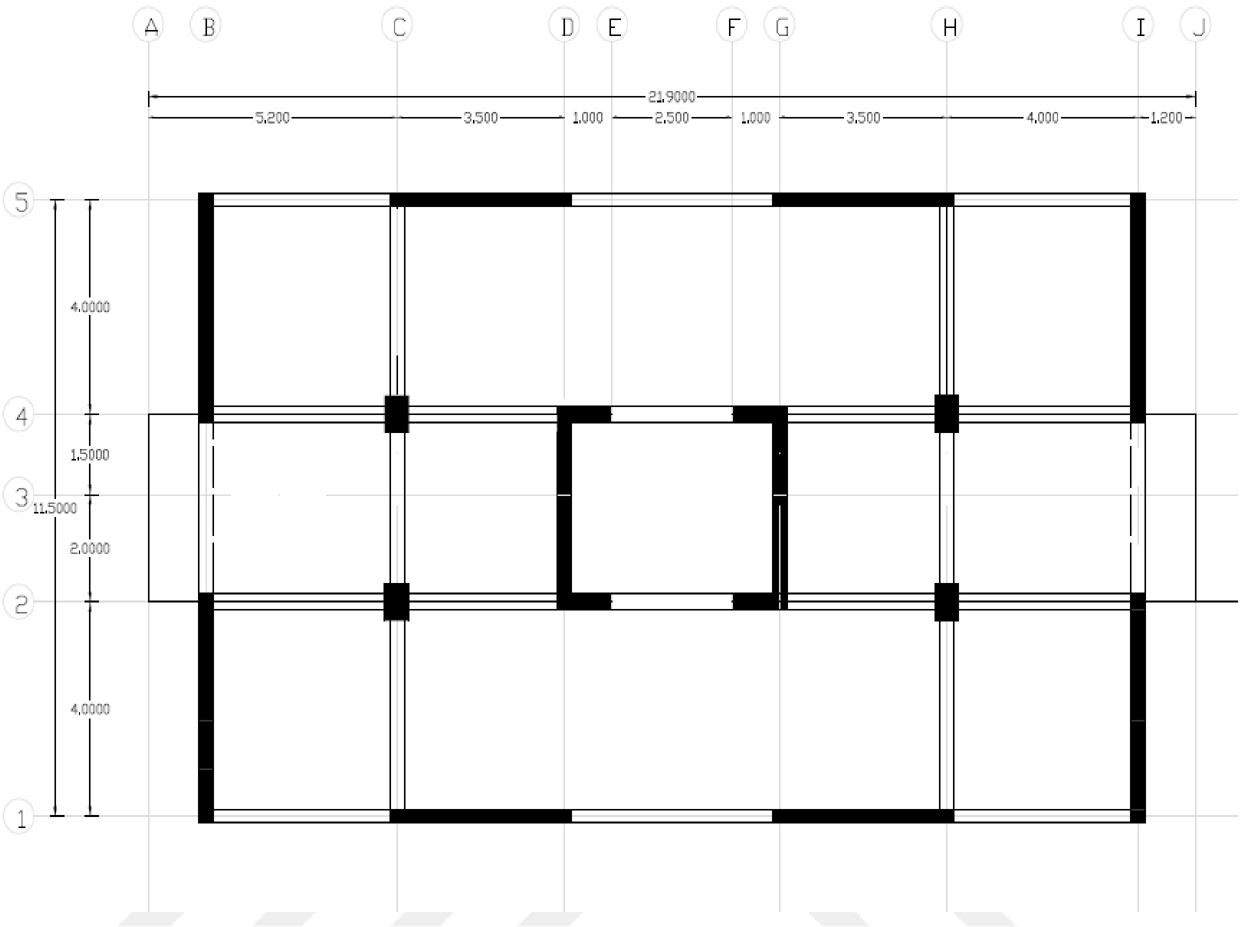


Figure 5.11: Slab with beams.

Reinforced detailing for slab with beams

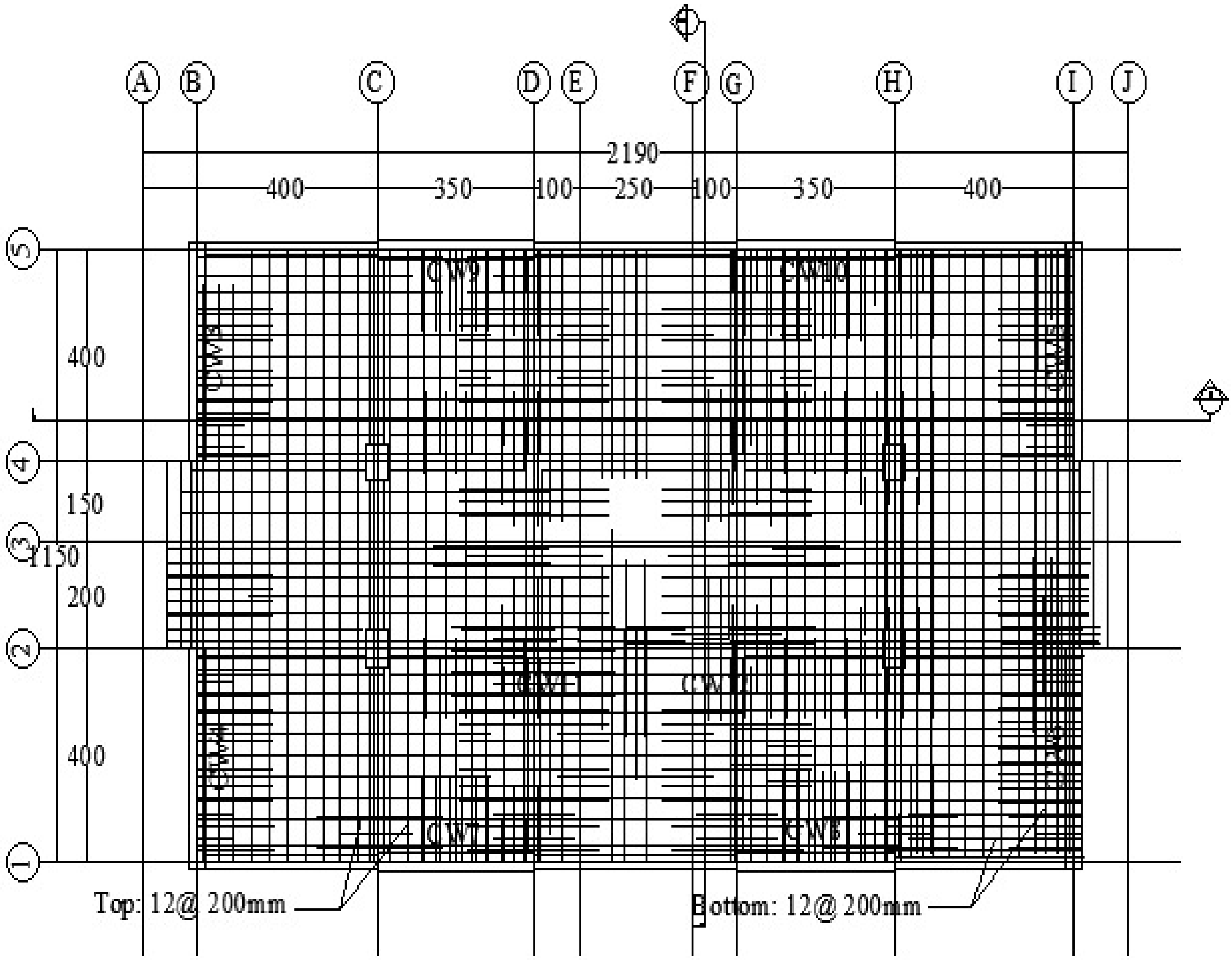


Figure 5.12: Reinforcement detailing for slab with beams.

Story drift

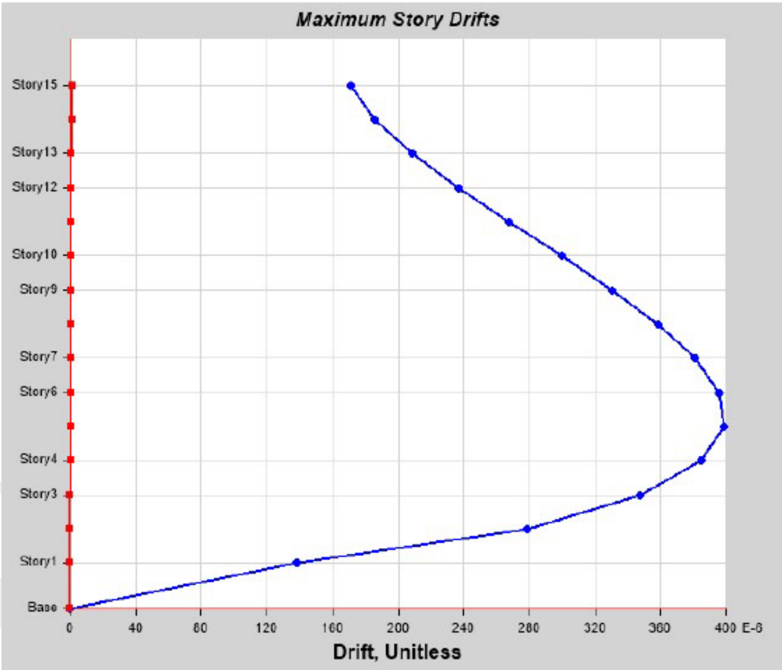


Figure 5.13: Maximum Story drift.

Story displacement

Figure 5.14: Maximum Story displacement.

5.2.5.2 Flat slab

Flat slab is a plate with two directions that does not present beams and the loads are transferred to the columns. These kinds of slabs may have a persistent thickness round its surface or in the surface of the columns it can have a thin thickness as a drop panel or column head or capital. These thickened areas are effective in reducing the shearing stresses where the column is likely to hit through the slab, and they further supply more moment resistant capacity where the negative moments are big. They have more advantages compared to the floor types as they have simplified formwork and reduce the height of the stories and also, they improve the esthetic of the building as the windows can be extended up to the underside of the slab.

In the code the minimum slab thickness h$\geq L_l/30$or h $\geq$200mm when the slab is used without column drop panel and column capital.

In this building the slab with the maximum lengths is 4500mm in long direction and 4000mm in the short direction, L_l=4500mm and $\frac{L_l}{30} = 150mm$. 200mm flat slab is used for these buildings and couple beams are used between the shear walls as perimeter beams.

The most important thing to check for these slabs is punching shear for columns as there is no beams between the slab and the column. The punching shear calculation is done by Etabs and the results are below one. The detailed calculation is summarized in the Annex.

Table 5.24: Flat Slab Period.

Flat Slab					
Direction	Period Used (sec)	S(T 1)	W (kN)	V (kN)	F N (kN)
X	1.318	0.963224	37183.0684	2046.608	230.2434
Y	1.266	0.994657	37183.0684	2113.395	237.757

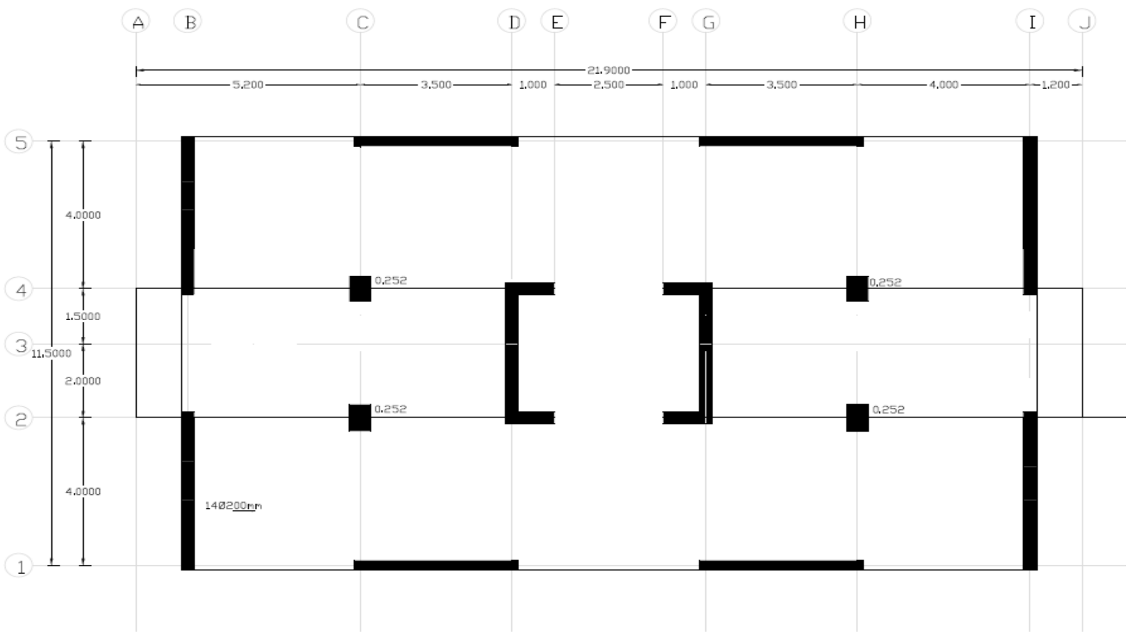


Figure 5.15: Flat Slab.

Reinforcement detailing for flat slabs

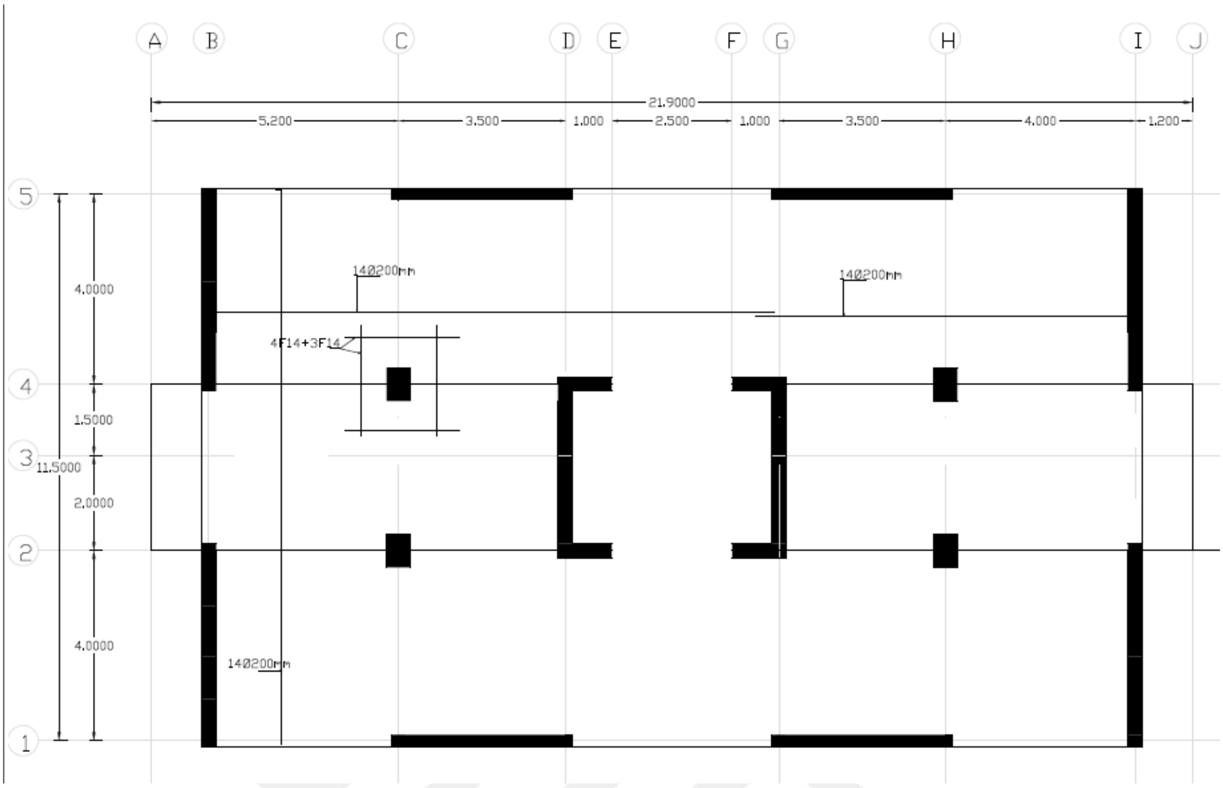


Figure 5.16: Reinforcement Detailing for Flat Slab.

Story drift

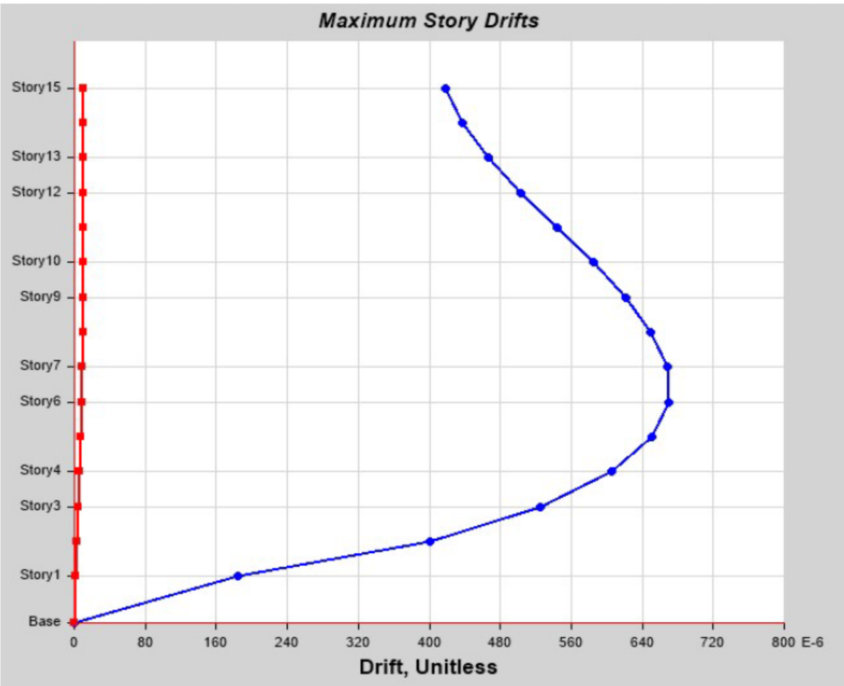


Figure 5.17: Maximum Story drift.

Story displacement

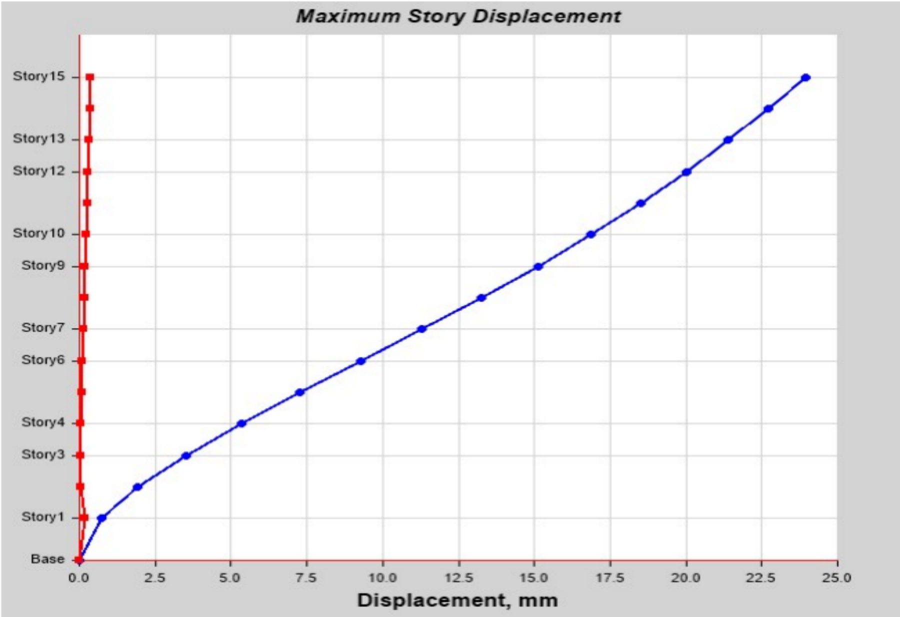


Figure 5.18: Maximum Story Displacement.

5.2.5.3 Ribbed slab

The directions of the ribs are generated to transfer as much weight as possible to the main beams located on the short axis. Frame elements in the modeling process refer to columns, frame beams and ribs. Slab elements are established as envelope elements between ribs and shear walls [12].

Table 5.25: Ribbed Slab Period.

Direction	Period Used (sec)	S(T 1)	W (kN)	V (kN)	F N (kN)
X	1.247	1.006505	39722.9244	2284.647	257.0228
Y	1.302	0.972493	39722.9244	2207.444	248.3375

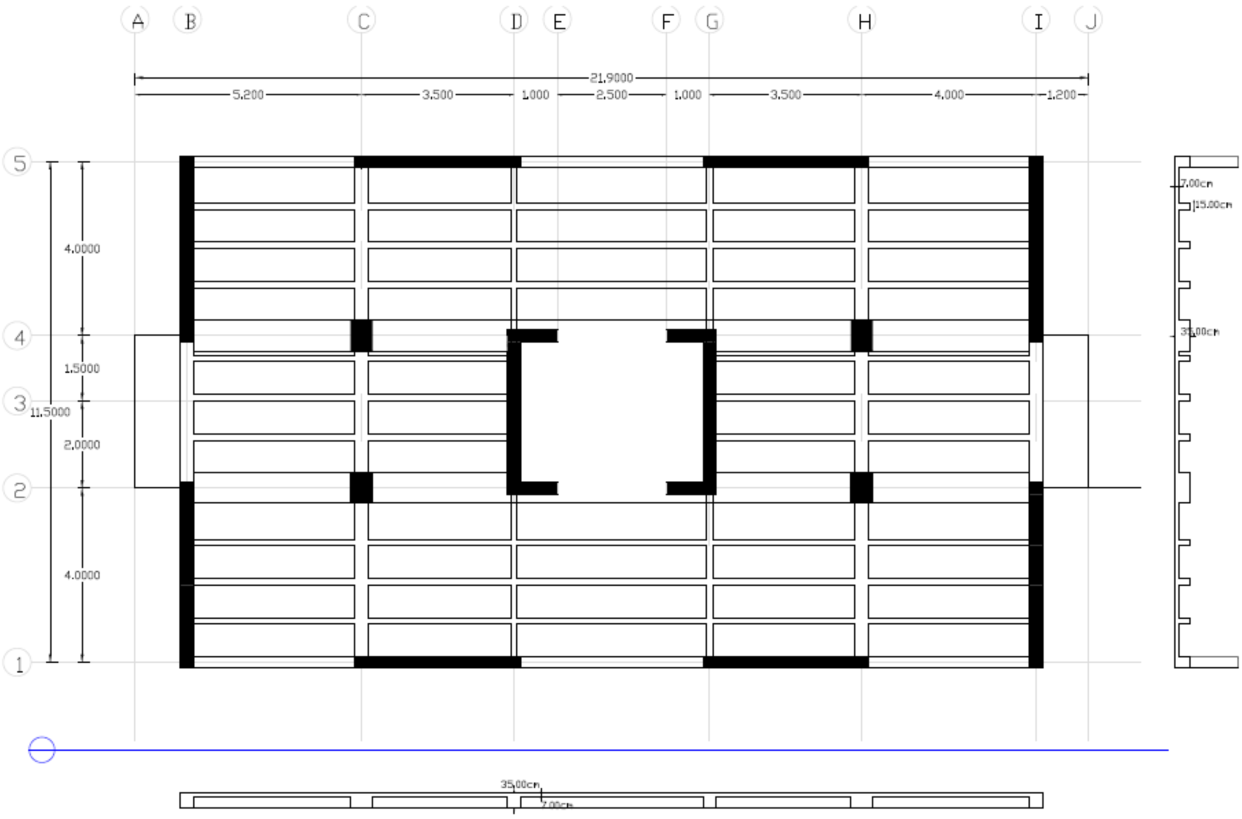


Figure 5.19: Ribbed Slab.

Dimensions

Whole slab Thickness is 35cm

Thickness of Slab 7 cm

Rib Depth is 28 cm

Rips Width 15 cm and

Rib Spacing is75cm

Reinforcement detailing for ribbed slabs

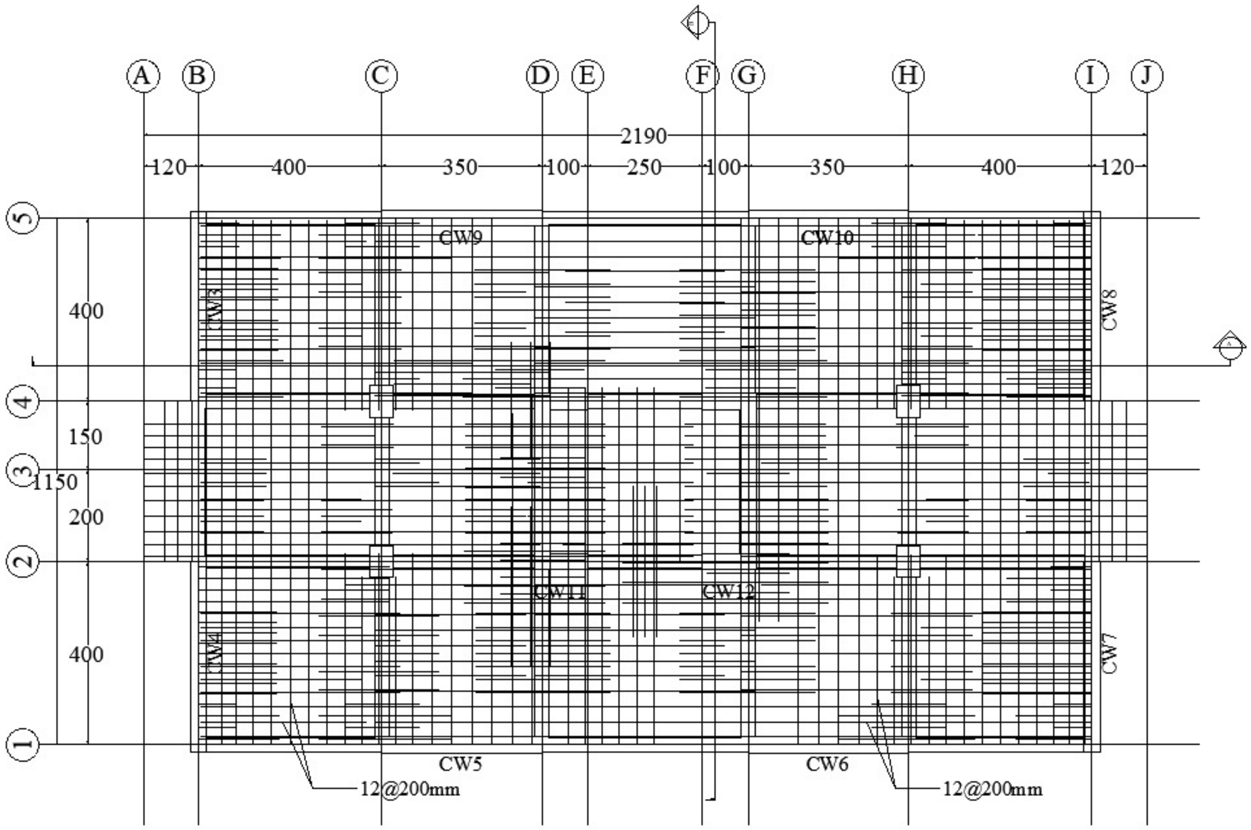


Figure 5.20: Reinforcement Detailing for ribbed Slab.

Story drift

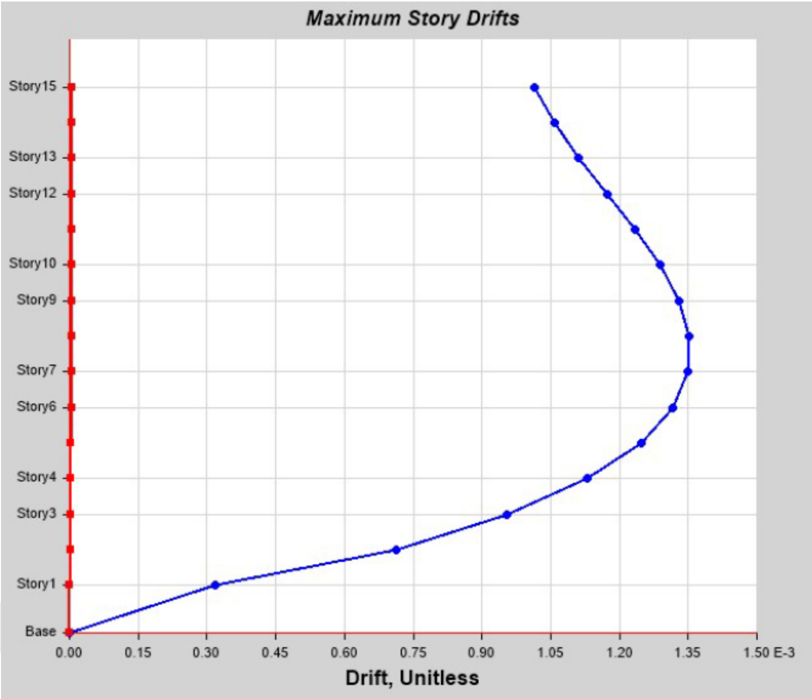


Figure 5.21: Maximum Story drift.

Story displacement

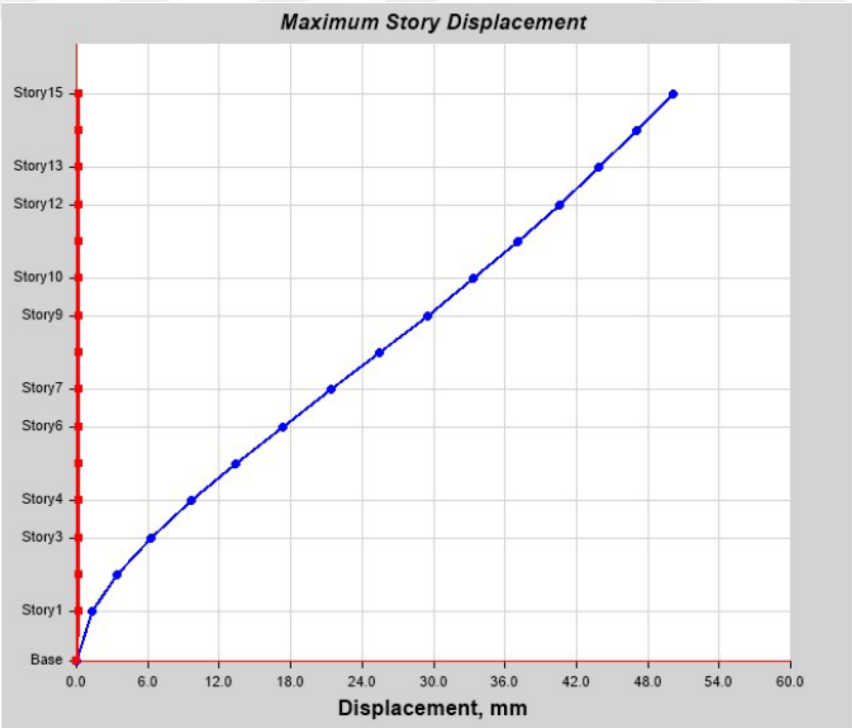


Figure 5.22: Maximum Story displacement.

Period Comparison

Table 5.26: Period Comparison.

Period			
Direction	Normal Slab	Flat Slab	Ribbed Slab
X	1.412	1.318	1.247
Y	1.45	1.266	1.302

6. CALCULATION OF MATERIALQUANTITIES AND COSTS

The total concrete, formwork and reinforcement quantities are calculated. The prices are according to Djibouti Francs and Turkish Lira, both the currencies are converted to US dollar. At the time being, 1 US dollar is 178DJF and 17.42 TL. The total building costs are compared and they are as follows.

6.1 WEIGHT OF REBAR (ton)

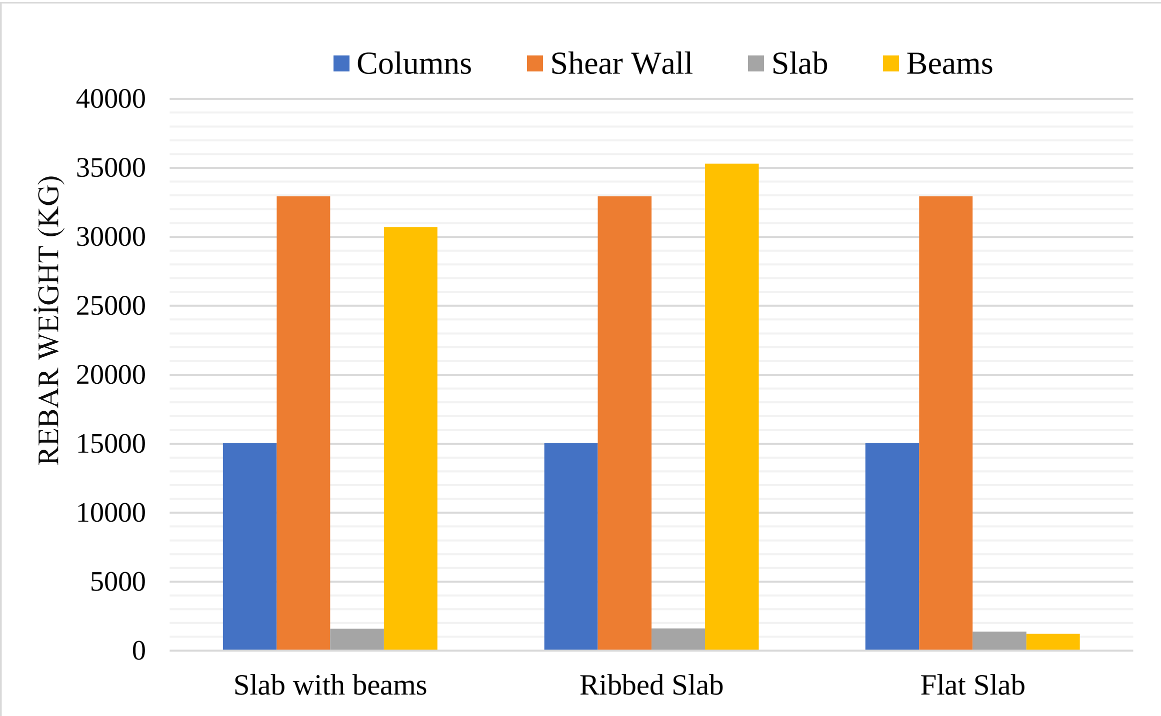


Figure 6.1: Weight of Rebar.

6.2 CONCRETE VOLUME (CUM)

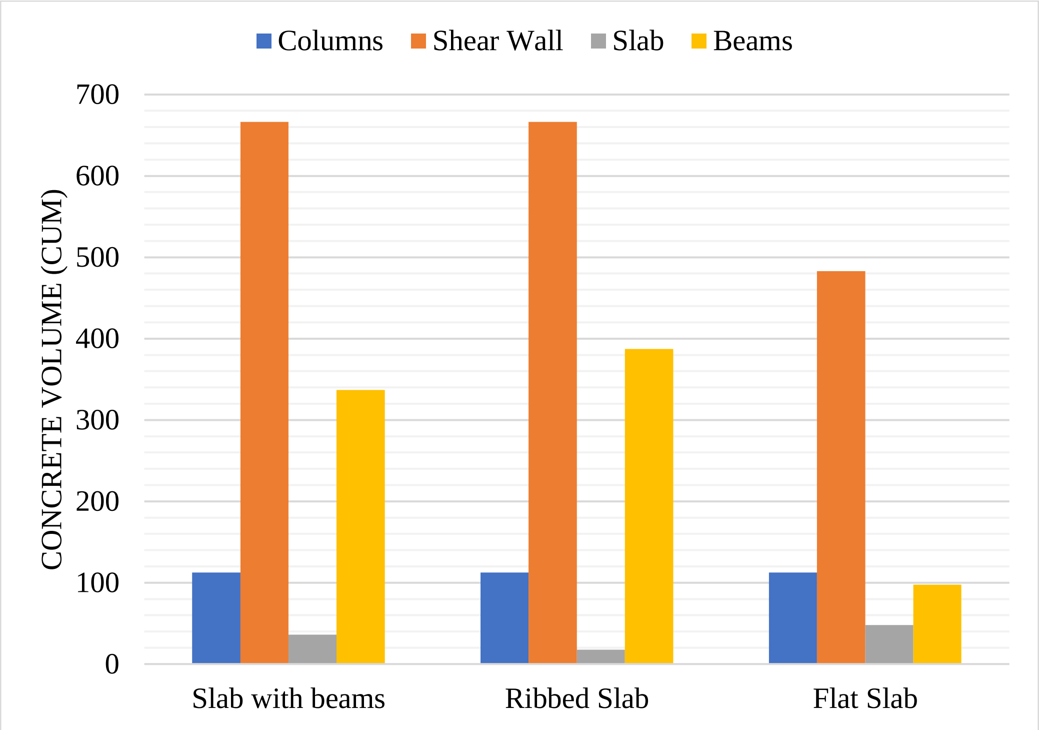


Figure 6.2: Concrete Volume.

6.3 FORMWORK(SQRM)

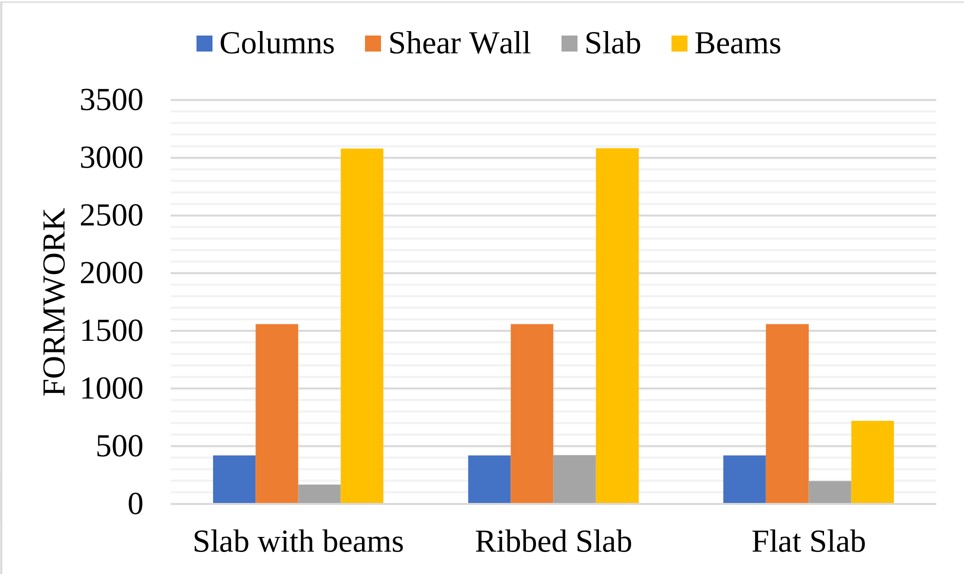


Figure 6.3: Formwork quantity.

6.4 COST COMPARISION

After designing the 15 story RC residential building three times with threedifferent types of floors, all the quantities of steel rebar and concrete are calculated, pricedand the final building cost according to Djiboutian Franc[17]and Turkish Lira[16] are as following.

6.4.1 Cost in Istanbul

Table 6.1: Cost comparison in Istanbul.

Elements	Slab with beams		
	Formwork (m2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	32944
Slab	167.44	36.157	1600
Beams	3078	336.84	30701
Total	5224.84	1152.156	80278
Price per Unit(TL)	148.86	960	10788
Total Price	777769.6824	1106069.76	866039064
Total Building Price ($)	**$4,871,601.88**		

Table 6.2: Cost comparison in Istanbul.

Elements	Ribbed Slab		
	Formwork (m2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	32944
Slab	421.89	17.545	1618
Beams	3080.7	387.366	35306.15
Total	5481.99	1184.07	84901.15
Price per Unit(TL)	148.86	960	10788
Total Price	816049.0314	1136707.2	915913606.2
Total Building Price ($)	**$5,151,968.05**		

Table 6.3: Cost comparison in Istanbul.

Elements	Flat Slab		
	Formwork (m2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	32944
Slab	198.84	47.79	1389.5
Beams	720	97.74	1228.04
Total	2898.24	924.689	50594.54
Price per Unit(TL)	148.86	960	10788
Total Price	431432.0064	887701.44	545813897.5
Total Building Price ($)	**$3,071,357.30**		

6.4.2 Cost in Djibouti

Table 6.4: Cost comparison in Djibouti.

ELEMENTS	Slab with beams		
	Formwork (m2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	12768
Slab	167.44	36.157	1600
Beams	3078	336.84	30701
Total	5224.84	1152.156	60102
Price per Unit(DJF)	3500	27000	270000
Total Price	18286940	31108212	16227540000
Total Building Price ($)	**$91,443,455.91**		

Table 6.5: Cost comparison in Djibouti.

ELEMENTS	Ribbed Slab		
	Formwork (m2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	12768
Slab	421.89	17.545	1618
Beams	3080.7	387.366	35306.15
Total	5481.99	1184.07	64725.15
Price per Unit(DJF)	3500	27000	270000
Total Price		31969890	17475790500
Total Building Price ($)	**$98,358,204.44**		

Table 6.6: Cost comparison in Djibouti.

ELEMENTS	Flat Slab		
	Formwork (m^2)	Concrete (m^3)	Rebars (Kg)
Columns	420	112.7	15033
Shear Wall	1559.4	666.459	12768
Slab	198.84	47.79	1389.5
Beams	720	97.74	1228.04
Total	2898.24	924.689	30418.54
Price per Unit(DJF)	3500	27000	270000
Total Price		24966603	8213005800
Total Building Price ($)	**$46,280,743.84**		

After comparing these three floor costs, we found that the building whose floors are flat slabs are more economical than the other two types whether they are built in Djibouti or in Istanbul.

7. CONCLUSION AND RECOMMENDATIONS

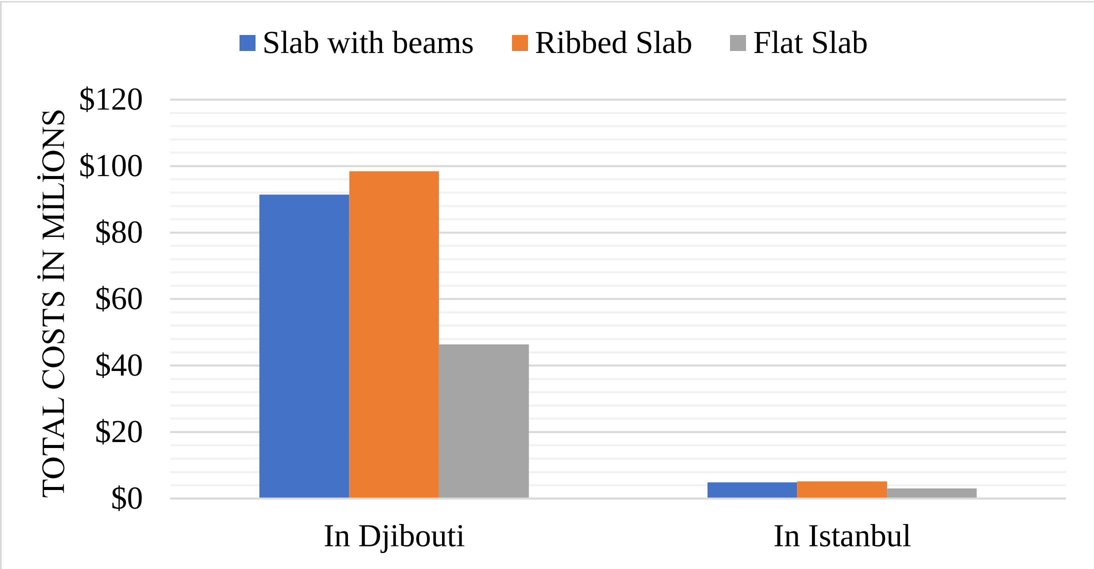


Figure 7.1: Cost Comparison.

After designing the 15 story RC residential building three times with three different types of floors (ribbed slab, flat slab and slab with beams at the perimeter) and the quantities of the materials are calculated, we found:

i. Buildings with flat slab are more cost-effective than the other structure types (Slab with beam-Ribbed slab)where ever they are in Djibouti or in Istanbul.

ii. The building with ribbed slab is less expensive than building with slab with beams in Istanbul but more expensive in Istanbul than slab with beams.

iii. In Djibouti flat slab is less expensive than ribbed slab by 7% and 6% than slab with beams, in Istanbul flat slab is less expensive than ribbed slab by 1% and 2% than slab with beams.

iv. Even though the slab with beams is more expensive than flat slab, in Djibouti they use it massively.

v. By comparing the periods of the buildings with the three slabs, we find that the normal slab has a higher period in both directions (x, y).

8. REMARK

The cost of construction being 1/5 in Djibouti compared to Istanbul, this is explained by the fact that the majority of construction products come from outside, notably from Turkey, according to the website www.wassel-group.com/, which is why construction products are more expensive in Djibouti than in Turkey. Regarding the prices of civil engineering products on the market, the state of Djibouti has not established a standard price grid of construction elements on the market according to our information from the company wassel-group based in the country which is involved in the sale of civil engineering construction materials: a company that served as a reference price for the project estimate.

REFERENCES

[1]From the Ground Up: Security for Tall Buildings. Dennis Challinger, 2008.

[2] The International Conference on Fire Safety in High-Rise Buildings emergency.

[3] High-Rise Security and Fire Life Safety:3rd EditionGeoff Craighead, May 7, 2009.

[4] Structural analysis:5th Ed. Mason, OH: Cengage Learning,A. Kassimali, 2013.

[5] Structural Analysis. R.C Hibbeler, 8th edition Pearson Education Ltd, London.2012.

[6] Seismicanalysisofstructures.T. K. Datta, Copyright _ 2010 John Wiley & Son

[7] Analysis and Design of Multi Storied Building by Using Etabs Software. V. Krishna, R. Chandrashekar, Vardhaman Coll, and Eng. Hyderbad. ISSN, pp. 2277–8179, 2015.

[8]Shear Wall Analysis and Design Optimization in Case of High-Rise Buildings Using Etabs. M. Pavani, G. N. Kumar, and S. Pingale, Int. J. Sci. Eng. Res., vol. 6, no. 1, 2015.

[9] Comparative Cost Study for A residential Building Using Different Types of Floor System.R. R. Nassar and I. A. Al-Qasem.

[10] A proposal for the classi_cation of structural systems of tall buildings: Building and Enviornment.M. HalisGunel and H. Emre Ilgin. 2006; 42(7): 2667-2675.

[11] Concrete Floor Systems: Guide to Estimating and Economizing.D. A. Fanella and P. C. Association, Portland Cement Association, 2000.

[12] Structural analysis and design of tall buildings: Steel and composite construction. CRC press, B. S. Taranath, 2016.

[13] Reinforced concrete design of tall buildings. CRC press,B. S. Taranath, 2009.

[14]The tall buildings reference book: Routledge. D. Parker and A. Wood, 2013.

[15] Design of tall buildings preliminary design and optimization. P. Jayachandran, 2009.

[16]T.C. ÇEVRE, ŞEHİRCİLİK VE İKLİM DEĞİŞİKLİĞİ BAKANLIĞI Yüksek Fen KuruluBaşkanlığı 1934.

[17]https://www.wassel-group.com