GENERAL COMPARISON AND EVALUATION OF TEC-2007 AND EC8 USING STA4-CAD V12.1 IN RESPECT OF COST ESTIMATION

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DECLARATIONS

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Dedicated with love to my parents and my sisters who have been always with me.....

ABSTRACT

Turkey and Cyprus has a long historical record of damaging earthquakes and life losses. In the last years, earthquake design of reinforced concrete structures becomes an important phenomenon due to disastrous earthquakes. In this study, Turkish Earthquake code 2007 (TEC-2007) and Eurocode 8 (EC8) design rules are examined and both regulations are compared. These two regulations are compared with each other in terms of cost according to results of three to seven storey reinforced concrete buildings. The reinforced concrete multi-storey buildings have been modeled by using STA4-CAD V12.1 package program, and as a result suggestions are presented.

Key words: *Eurocode 8, Turkish Earthquake code 2007, Reinforced Concrete Building, STA4-CAD V12.1.*

ÖZET

Türkiye ve Kıbrıs'ta, geçmişten günümüze kadar gelen, kayıda geçmiş depremler ve bundan kaynaklanan ciddi kayıplar olmuştur. Son yıllarda, depreme karşı dayanıklı binalar, afet oluşturan depremlerden dolayı önem kazanmıştır. Bu çalışmada, Türk deprem yönetmeliği 2007 (TDY-2007) ve Eurocode 8 (EC8) tasarım kuralları incelenmiş ve iki yönetmelik, kat sayısı üç'den yedi'ye kadar olan betonarme konut yapısı için, analiz sonuçlarına göre maliyet açısından karşılaştırılmıştır. Çok katlı betonarme binalar, STA4-CAD V12.1 bilgisayar programı kullanılarak analizi ve tasarımı yapılmıştır. Sonuçlar maliyet açısından değerlendirilmiş ve öneriler sunulmuştur.

Anahtar kelimeler: *Eurocode 8, Türk deprem yönetmeliği 2007, betonarme binalar, STA4-CAD V12.1.*

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LIST OF ABBREVIATIONS

EC8	Eurocode 8 (Design of Structure for Earthquake Resistance)
TEC-2007	Turkish Earthquake Code 2007
TRNC	Turkish Republic of Northern Cyprus
CEN	Committee European de Normalization
UBC	Uniform Building Code
IBC	International Building Code
EC2	Eurocode 2 (Design of Concrete Structures)
TS-498	Design Loads for Building
TS-500	Requirements for Design and Construction of Reinforced Concrete Buildings
DCH	High Ductility Building Member
DCM	Medium Ductility Building Member
DCL	Low Ductility Building Member
NDL	Nominal Ductility Building Level
HDL	High Ductility Building Level

LIST OF SYMBOLS

c_u	Undrained shear strength of soil.
$v_{s\,30}$	Average value of propagation velocity of *S* waves in the upper 30 m of the soil. profile at shear strain of 10–5 or less.
N_{SPT}	Standard penetration test blow-count.
T	Vibration period of a linear single degree of freedom system.
T_B	Lower limit of the period of the constant spectral acceleration branch.
T_C	Upper limit of the period of the constant spectral acceleration branch.
T_D	Value defining the beginning of the constant displacement response range of the spectrum.
S	Soil factor.
T_{NCR}	Reference return period of the reference seismic action for the no-collapse requirement.
P_{NCR}	Reference probability of exceedance in 50 years of the reference seismic action for the no-collapse requirement.
a_g	Design ground acceleration on type A ground.
a_{gR}	Reference peak ground acceleration on type A ground.
$S_e(T)$	Elastic response spectrum.
η	Damping correction factor with a reference value of η=1 for 5% viscous damping.
ξ	Viscous damping ratio of the structure, expressed as a percentage.
$S_{De}(T)$	Elastic displacement response spectrum.
$S_{ve}(T)$	Elastic vertical ground acceleration response spectrum.
$S_d(T)$	Design spectrum (for elastic analysis).
a_{vg}	Design ground acceleration in the vertical direction.
γ_{I}	Importance factor.
$\mathrm{M_s}$	Magnitude.
q	Behavior factor.
β	Lower bound factor for the horizontal design spectrum.
G_{kj}	Characteristic value of dead loads.

A_{Ed}	Design value of return period of specific earthquake motion.
ψ_{2i}	Characteristic value of live load.
Q_{ki}	Combination coefficient for variable action *I*.
λ	Slenderness.
L_{max}	Larger dimension in plan of the building.
L_{min}	Smaller dimension in plan of the building.
e_{ox}	Distance between the center of stiffness and the center of mass, measured along the x direction, which is normal to the direction of analysis considered.
r_x	Square root of the ratio of the torsional stiffness to the lateral stiffness in the y direction (“torsional radius”).
l_s	Radius of gyration of the floor mass in plan (square root of the ratio of (a) the polar moment of inertia of the floor mass in plan with respect to the center of mass of the floor to (b) the floor mass).
I	Building importance factor.
$A(T)$	Spectral acceleration coefficient.
A_0	Effective ground acceleration coefficient.
$S(T)$	Spectrum coefficient.
$S_{ae}(T)$	Elastic spectral acceleration.
g	Gravity coefficient.
T_A, T_B	Spectrum characteristic periods
E_d	Load Combinations.
G	Dead load.
Q	Live load.
E_n, E_y	Earthquake in direction to *n*.
g_i	Total live load at i’th story of the building.
q_i	Total dead load at i’th story of the building.
n	Live load participation factor.
N	Number of stories in the structure.
η_{bi}	Torsionally irregularity factor defined at i’th storey of the building.
$(\Delta_i)_{ort}$	Average storey drift of i’th storey of the building.

$(\Delta_i)_{max}$ Maximum storey drift of i'th storey of the building.

$(\Delta_i)_{min}$ Minimum storey drift of i'th storey of the building.

A_b Total area of openings.

A Gross floor area.

Lx, Ly Length of the building at x, y direction.

a_y, a_x Length of re-enter corners in x, y direction.

A_e Effective shear area.

A_w Effective of web area of column cross sections.

A_g Section areas of structural elements at any storey.

A_k Infill wall areas.

η_{ki} Stiffness irregularity factor defined at i'th storey of the building.

Δ_i Storey drift of i'th storey of the building.

h_i Height of i'th storey of building [m].

h_w Height of wall or cross-sectional depth of beam.

f_{ctm} Mean value of tensile strength of concrete.

f_{yk} Characteristic yield strength.

ρ Tension reinforcement ratio.

ρ_{min} Minimum tension reinforcement ratio.

ρ_{max} Maximum tension reinforcement ratio.

ρ' Compression steel ratio in beams.

ε_{sy} Design value of steel strain at yield.

h_c Cross-sectional dimension of column.

ρ_w Shear reinforcement ratio.

d_{bw} Diameter of hoops.

d_{bL} Longitudinal bar diameter.

b_{wo} Thickness of web.

l_c Clear Column Length.

ρ_l Total longitudinal reinforcement ratio.

s Spacing.

ω_{wd} Ratio of the volume of confining hoop to that of confined core to the centerline of the parameter hoop, times f_{yd}/f_{cd} .

α	Confinement effective.
b_c	Cross sectional-dimension of column.
b_o	Width of confined core in a column or in the boundary element of a wall (to centerline of hoops).
ρ_w	Shear reinforcement ratio.
ρ_v	Reinforcement ratio of vertical web bars in a wall.
N_{Ed}	Axial force from the analysis for the seismic design situation.
A_c	Gross section area of column.
f_{cd}	Design value of concrete compressive strength.
l_{ot}	Distance between torsional restraints.
b	Total depth of beam in central part of $l_{ot.}$.
h	Width of compression flange.
b_w	Width of primary seismic beam.
h_w	Depth of beam.
h_s	Clear storey height in meter.
N_d	Axial force calculated under combined effect of seismic loads and vertical loads. multiplied with load coefficients.
f_{ck}	Characteristic compressive cylinder strength of concrete.
A_g	Gross sections area of or wall end zone.
A_p	Plane area of Storey building.
Vt	Total seismic load acting on a building.
f_{ctd}	Design tensile strength of concrete.
N_{dmax}	Greater of the axial pressure forces calculated under combined effect of seismic loads and vertical loads.
f_{ctm}	Main value tensile strength of concrete.
f_{yk}	Characteristic yield strength.
μ_φ	Value of the curvature ductility factor.
μ_ϖ	Design value of steel at yield.
f_{yd}	Design value of yield strength of steel.
v_d	Column axial load ratio.

A_c	Column cross-section area.
l_c	Length of the column.
h_c	Largest cross-sectional dimension of the columns (in meters).
h_o	Depth of confined core in a column (to centerline of hoops).
b_o	Core with length
l_w	Long side of the rectangular wall section.
H_w	Total height of the wall.
h_s	Storey height
v_d	Wall axial load ratio
ρ_h	Reinforcement ratio of horizontal web bars in a wall.
D_{bar}	Diameter of longitudinal rebars.
D_{min}	Smallest dimension of beam cross-section
a	Lateral distance between legs of hoops and crossties
N_d	Axial force calculated under combine effect of seismic loads and vertical loads multiplied with loads coefficients
A_{ck}	Concrete core area within outer edges of confinement reinforcement.
f_{ywk}	Characteristic yield strength of transverse reinforcement.
A_{sh}	Total area steel of hoops

Chapter I

1. INTRODUCTION

1.1. Background of the Study

An earthquake is ground shaking caused by a sudden movement of rock on the earth's crust. Such movements occur along faults, which are thin zones of crushed rock separating blocks of crust. When one block suddenly slips and moves relative to the other along a fault, the energy released creates vibration called seismic waves, which radiate up through the crust to the Earth's surface, causing large horizontal and vertical ground motion. These ground motion translate into inertia force in structures and cause rapid shaking of the structures which could lead to serious damage or collapse [1, 2]. Earthquakes represent a major natural hazard, resulting in loss of life and economic losses due to damage to buildings and businesses. More than 300000 earthquakes occur on the earth every year. Many of these are of small intensity and do not cause any damage to the structures. However, earthquakes of larger intensity that hits of populated areas cause considerable damage structures and loss of life [3]. In general the occurrence of the earthquakes depends on the seismic activity of that area that is occurring on. Some places on the earth have low seismic activity and some places have high seismic activity due to their geological formation. This fact is clearly seen in the global seismic hazard map in figure 1.1.

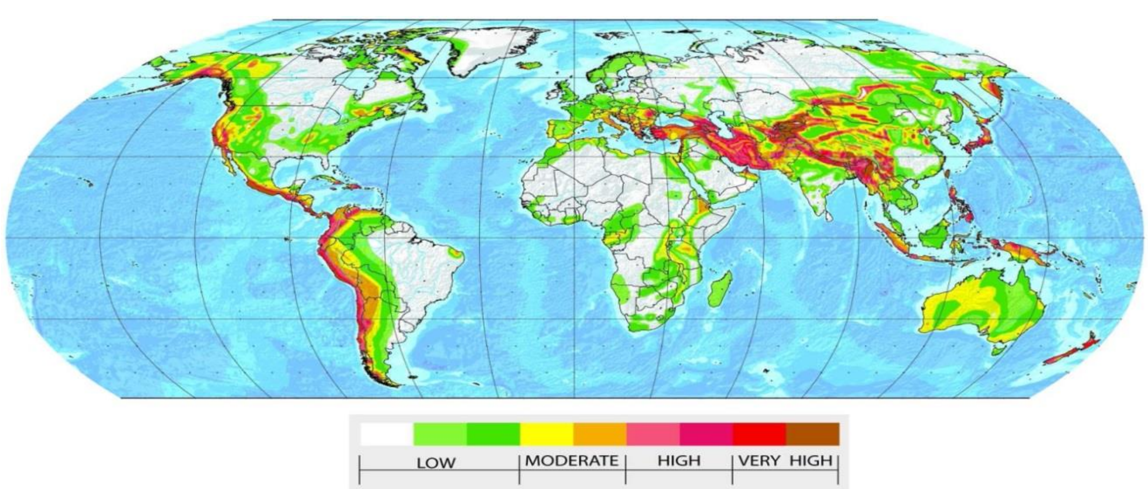


Figure 1.1 Map of Global Seismic Hazard [4].

In the last years there are many disastrous earthquakes occurred which caused a big human tragedy all around the world. Recent significant earthquakes around the world in the last 10 years are shown in Table 1.1.

Table 1.1 Recent Significant Earthquakes in the Last 10 Years in the World [5].

Year	Location	Fatalities	Magnitude
2003	Iran	31,000	6.6
2004	Sumatra	227,898	9.1
2005	Pakistan	86,000	7.6
2006	Indonesia	5,749	6.3
2008	China	87,587	7.9
2010	Haiti	222,570	7.0
2011	Japan	15,867	9.1
2012	Iran	306	6.4 & 6.3

Turkey and Cyprus are one of the most hazard area in the world. This fact is clearly seen in the global seismic hazard map in figure 1.1. In this map, countries like Japan, Italy and west side of USA have also warm colors that shows high risks like Turkey and Cyprus.

Turkey is in the third place in the world in terms of relative risks of earthquakes. It is located in the Anatolian plate between three active tectonics plates which is Eurasian plate from the North, Arabian plate from the Southeast and African plate from South which is considered as a highest active earthquakes sector in the world. Alp-Himalayan fault line is the reason for the many earthquakes in Turkey [6]. Turkey has three significant faults; North Anatolian fault, South Anatolian fault, West Anatolian fault, as shown in figure 1.2.

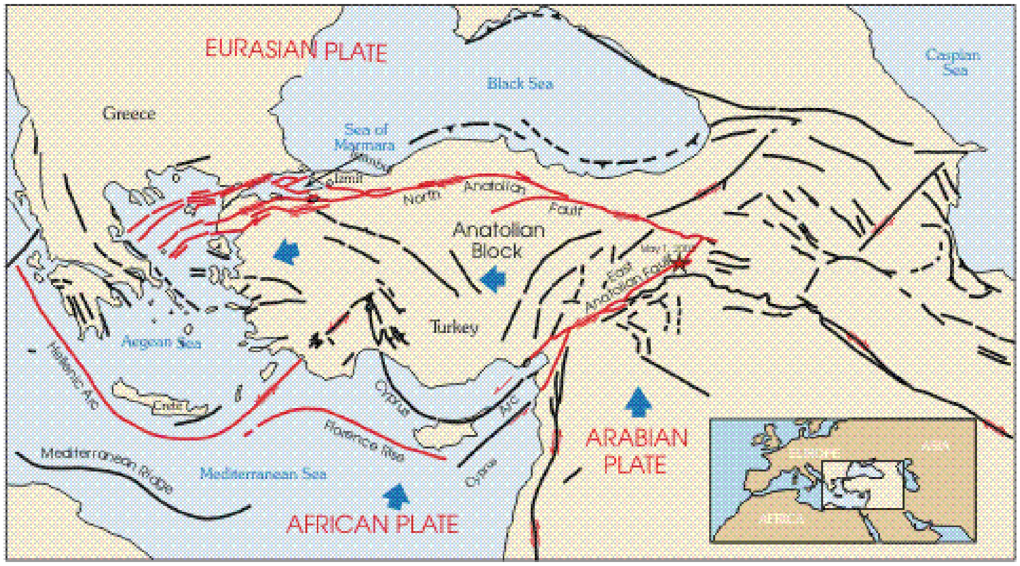


Figure 1.2 Tectonic Map of Turkey and Cyprus [6].

Figure 1.2 shows the tectonic map of Turkey and Cyprus and their locations form the tectonics plates. The red lines shows the significant faults, the black lines shows the plate boundaries, the blue arrows shows the direction of movements of these tectonics plates.

The recent earthquakes resulting in loss of life due to serious damages in last 10 years in Turkey are shown in table 1.2.

Table 1.2 Recent Significant Earthquakes in the Last 10 Years in Turkey [5].

Year	Location	Fatalities	Magnitude
2002	Afyon	44	6.5
2003	Bingöl	177	6.4
2005	Seferihisar-Izmir	-	5.9
2005	Hakkari	3	5.4
2010	Elazığ	41	6.1
2011	Kütahya	2	5.8
2011	Van	604	7.2
2012	Fethiye, Muğla	-	6.0

An official seismic hazard zonation map for Turkey was prepared recently by the Ministry of Public Works and Settlement considering the latest knowledge of earthquakes which divides Turkey into five seismic zones according to their seismic activity, as seen in figure1.3, where the places with warm colors considered as high seismic activity.

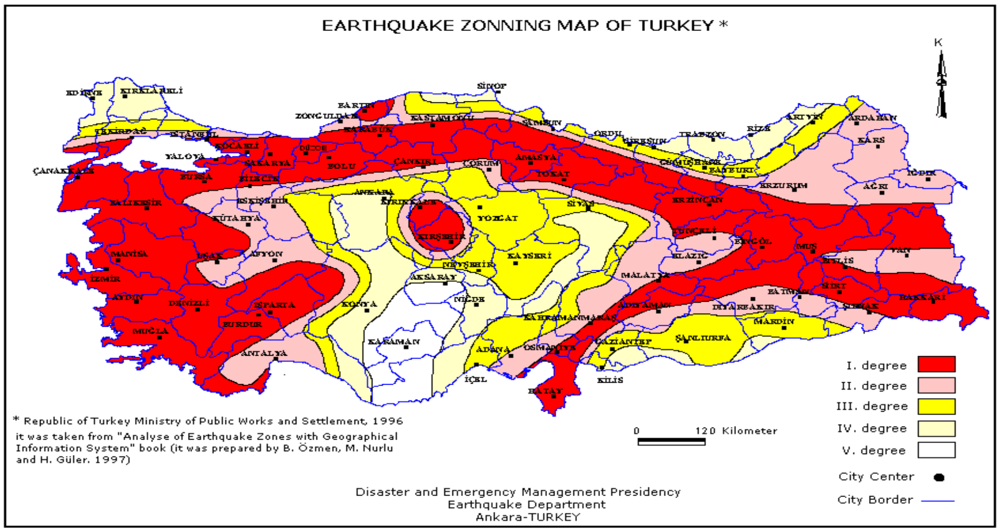


Figure 1.3 Seismic Hazard Zonation Map of Turkey [7].

Cyprus is an island which is located in the Eastern Mediterranean sea, between East 35˚ and East 32˚ longitudes lines, North 36˚ and North 34˚ latitudes lines. Cyprus lies within the second largest earthquake stricken zone of the earth, but in a relatively less active sector. The level of the seismic activity in the Cyprus region is significantly lower than that in Greece and Turkey as it is observed in figure 1.1. This zone stretches from the Atlantic Ocean across the Mediterranean Basin, through Greece, Turkey, Iran, and India as far as the Pacific Ocean. The energy released by the earthquakes in this zone represents 15% of the universal seismic energy [8]. It is located in active seismic zones which in Cyprian arc, Anatolian plate from the North, Arabian plate from East and African plate from the South as shown in figure 1.2 [6]. Because of that Cyprus has a rich history of earthquake events. Many destructive earthquakes have struck Cyprus over its long history and many of its towns and villages have been destroyed by strong earthquakes, as shown in figure 1.4.

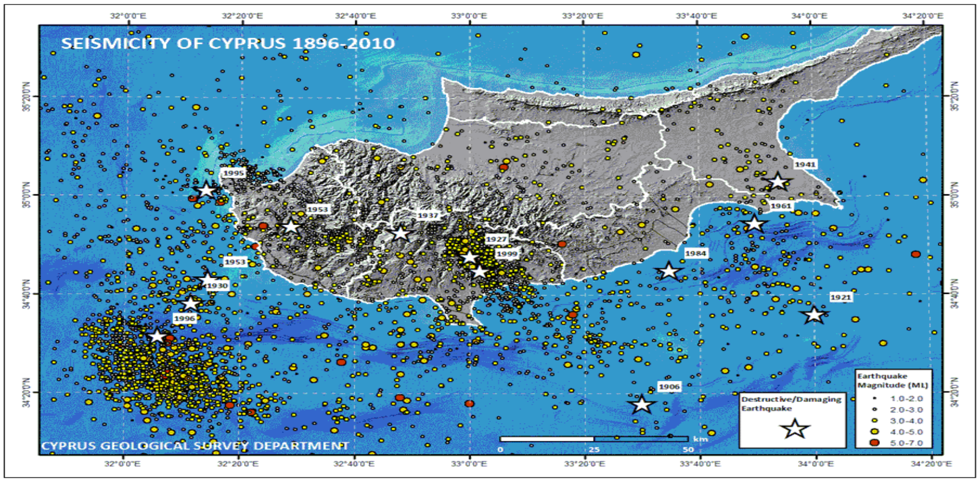


Figure 1.4 Map of Seismicity of Cyprus from 1896 – 2010 [9].

The recent earthquakes in Cyprus in the last 10 years are shown in the table 1.3.

Table 1.3 Recent Significant Earthquakes in Last 10 Years in Cyprus [10].

Year	Location		Magnitude
	Latitudes	Longitudes	
2002	35.262˚ N	32.712˚ E	4.1
2003	34.158˚ N	34.509˚ E	4.3
2004	34.805˚ N	32.739˚ E	5.0
2005	34.439˚ N	32.141˚ E	4.4
2006	34.910˚ N	33.961˚ E	4.3
2007	34.962˚ N	33.506˚ E	4.1
2009	34.680˚ N	33.003˚ E	4.5
2010	34.789˚ N	30.014˚ E	4.4
2011	34.429˚ N	32.155˚ E	4.0
2012	34.293˚ N	34.129˚ E	5.0

Design building codes play a crucial role to avoid the designer of making a major mistakes which could led to a big human tragedy.

Design building codes in general are legal documents which represented the minimum requirements for obtaining safe structures and these codes are written by responsible people with wide knowledge and experience of engineering. It is not necessarily describes the best practice. But in general helps the structural engineers to design and establish a safe structure and helps to avoid making the major mistakes. In general, safety cannot be defined independent of economy. A structure which is safe may not necessarily be considered as successful engineering structure if it is not economical [11].

Devastating earthquakes hits all around the world and caused many deaths and injuries and left a lot of structures with substantial damage because of their weakness to withstand in the earthquake events due to poor detailing of seismic resisting building according to inadequate design codes. Since then many seismic codes were published in all around the world [11].

Anatolian lands have been exposed to big disasters since the beginning of written history. In the last years earthquake design of structures becomes an important phenomena due to disaster earthquakes which caused a big human tragedy. These earthquakes show that the buildings have low seismic performance due to the usage of low quality material, low quality of workmanship and inadequacy of the design codes. Since then many new codes detailing requirements have been introduced to ensure seismic resistance. After the 1999 Marmara earthquake, which was the most hazardous earthquake of Turkey in the last century, the provisions have been added to the Turkish earthquake code. 1998 disaster regulation was revised in 2007 in which the new regulation was called "Specifications for Buildings to be Built in Earthquake Areas" and it came into effect on March 2007 [12].

On the other hand the development of Eurocode has started in 1975 by the European Committee for Standardization or Committee European de Normalization (CEN). It is a non-profit organization whose mission is to develop the European economy in global trading, the welfare of European citizens and the environment by providing an efficient infrastructure to interested parties for the development, maintenance and distribution of coherent sets of standards and specifications. European earthquake regulation is "Eurocode 8" called "Design of Structures for Earthquake Resistance"**.** The Eurocodes are common set of building codes in Europe. At the moment, they are still in the trial phase. These codes are frequently used between countries which are members of European Union [13].

Z. Çağnan and G. B.Tanırcan published an original article regarding the probabilistic seismic hazard assesment of Cyprus. In this study it was stated that the uniform hazard spectra clearly indicate the urgent need for adoption of EC8 in the northern part of the island [14].

The seismic hazard map of Cyprus was originated by Ergunay and Yurdatapan in 1973, Computing the four zoned seismic hazard map of Cyprus. Then developed by the Repuplic of Cyprus, Geological and Survey department. It has been extended by both M. Erdik et al, and O. Can, in 1997. They present a study regarding the seismic hazard of Cyprus using Cornell probabilistic approach and computed peak ground acceleration (PGA) which is a measure of earthquake acceleration on the ground [15,16].

As part of the preparations for the National Annex of Cyprus to Eurocode 8 (EC8), the Geological Survey Department of Republic of Cyprus revised its 1992 seismic zonation map. In the revised map, the previous zones were completely preserved; however, corresponding PGA values were modified. The map shown below is the latest seismic zonation map prepared for Cyprus and is currently being used for seismic design in the southern part of the island [14]. See figure 1.5.

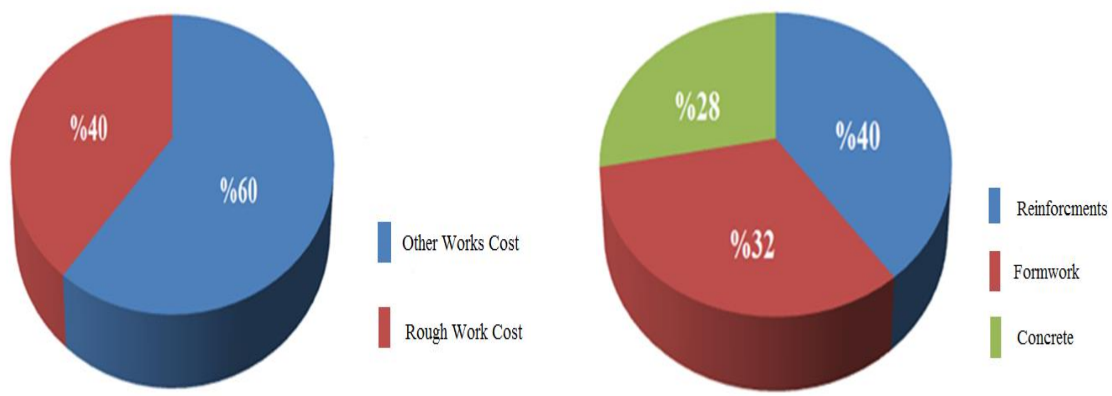
Figure 1.5 Seismic Zonation Map of Cyprus [17].

For the northern part of the island currently, there are no detailed and official seismic zone map.

Reinforced concrete is the most common building material in Turkey and Cyprus. In general for multi-storey reinforced concrete building, the rough works constructions cost, correspond of approximately 40% of major construction cost of reinforcement concrete building. Rough works construction cost analysis includes [18]:

- Concrete materials, equipment, and labor for placing, curing, and finishing the concrete.
- Reinforcing steel and its placement.
- Formwork including labor, equipment, and materials.

Typical distributions of rough work constructions cost for reinforced concrete building, in percentage are showing in figure 1.5.



a. Total Construction cost Distributions. b. Rough Work Cost Distributions.

Figure 1.6 Typical Distributions of Reinforced Concrete Building Construction Costs.

1.2. Aim of the Study

In the recent year been a great need for understanding of construction economics particularly during the design stage of projects. Economics in general is about the choice of the ways which limited of resource and ought to allocate between all their possible uses. The study of cost is about understanding and application of costs to building and other structures. One of its aims is to ensure that limited resources are used to best advantage. The aims of engineering are to design and establish a structure which minimizes the construction cost while meeting all the safety and quality requirements [18].

In this study Eurocode 8 (EC8) [19], and Turkish Earthquake Code 2007 (TEC-2007) [20], will examined and compared with each other to find out the difference and the similarity between these two codes.

The very first goal as engineers is to build reliable structures that do not threaten human life. After that, meet the expectations of the employer or the consumer functional sense, in terms of cost to provide optimum cost effective solutions. Building cost in construction industry is very important, as in all other sectors.

This document consists of six chapters. The purpose of the study and basic information is given in chapter one. In the second chapter, general principles and rules of earthquake resistant buildings using both EC8 and TEC-2007 are examined. In the third chapter, general rules for the resistance structural systems are mentioned. In the fourth chapter, special design rules for reinforced concrete building are examined separately for both regulations. In the fifth chapter, the structure of three, four, five, six and seven storey reinforced concrete building analysis is made by using STA4-CAD V12.1 computer program. In the sixth and last chapter, the cost calculated for both codes are compared and as a result, suggestions are presented.

1.3. Previous Studies

In the course of this investigation, a review of the broader literature in the area of code comparisons between EC8 and TEC-2007 was undertaken. Many papers were published since 2000, mainly journal articles and World Earthquake Engineering Conference papers and European Conference on Earthquake Engineering papers, were reviewed as part of this study. In the interest of space, only a brief summary is given below;

- A. Dogangun and R. Livaoglu (2006), present "*A Comparative Study of the Design Spectra Defined by Eurocode 8, UBC, IBC and Turkish Earthquake Code on R/C Sample Buildings*". In this study, the design spectra recommended by Turkish Earthquake Code and three other well-known codes (Uniform Building Code, Eurocode 8, and International Building Code) are considered for comparison. The main purpose of this study is to investigate the differences caused by the use of different codes in the dynamic analysis and seismic verification of given types of buildings located at code defined different sites. The differences in expressions and some important points for elastic and inelastic spectra defined by the codes are briefly illustrated in tables and figures. Periods, base shears, lateral displacements and interstory drifts for the analyzed buildings located at code defined ground type are comparatively presented in this study [21].

- A. Dogangun and R. Livaoglu (2006), present a study "*Comparison of Seismic Analysis methods of Multi Storey Building*", this study is to examine the differences in results obtained by Equivalent Seismic Load Method, Mode-Superposition Method and Analysis Method in Time Domain. These three seismic analysis methods are included in the TEC-1997 and EC8. But, there are some differences between TEC-1997 and EC8 requirements for these methods. The Finite Element Method is used for modeling of buildings. SAP2000 package program is used to analysis of selected buildings subjected to earthquake. The results obtained by these different methods for the buildings have been compared with each other's [22].

- E. Toprak; F. Gülten Gülay and P. Ruge (2008), present their study which is "*Comparative Study on Code-based Linear Evaluation of an Existing RC Building Damaged during 1998 Adana-Ceyhan Earthquake*", which is a comparative study is performed on the code-based seismic assessment of reinforced concrete buildings with linear static methods of analysis, selecting an existing reinforced concrete building. The basic principles dealing the procedure of seismic performance evaluations for existing reinforced concrete buildings according to Eurocode 8 and TEC-2007 was outlined and compared. Then the procedure is applied to a real case study building is selected which is exposed to 1998 Adana- Ceyhan Earthquake in Turkey, the. It was reported that the building had been moderately damaged during the 1998 earthquake and retrofitting process was suggested by the authorities with adding shear-walls to the system. The computations show that the performing methods of analysis with linear approaches using either Eurocode 8 or TEC-2007 independently produce similar performance levels of collapse for the critical storey of the structure. The computed base shear value according to Eurocode is much higher than the requirements of the Turkish Earthquake Code while the selected ground conditions represent the same characteristics. The main reason is that the ordinate of the horizontal elastic response spectrum for Eurocode 8 is increased by the soil factor. In TEC-2007 force-based linear assessment, the seismic demands at cross-sections are to be checked with residual moment capacities; however, the chord rotations of primary ductile elements must be checked for Eurocode safety verifications. On the other hand, the demand curvatures from linear methods of analysis of EC8 together with TEC-2007 are almost similar [23].

- Z. Çağnan and G. Tanırcan present their study which is "*Seismic Hazard Assessment for Cyprus*". In this study, probabilistic seismic hazard assessment was conducted for Cyprus based on several new results: a new comprehensive earthquake catalog, seismic source models based on new research, and new attenuation relationships. Peak ground acceleration distributions obtained for a return period of 475 years for rock conditions indicate high hazard along the southern coastline of Cyprus, where the expected ground motion is between 0.3g and 0.4g. The rest of the island is characterized by values representing less severe shaking. Results of this study strongly indicate the inadequacy of the Turkish Earthquake Code that is being used in the northern part of the island and the Eurocode 8 that is in effect in the southern part of the island to approximate the uniform hazard spectra developed for the high hazard and moderate hazard regions of the island [14].

- B. Bayhan and P. Gülkan (2000), present a study, "*Is There Disarray in Descriptions of Performance Requirements*?", this study aims to investigate the correctness of existing assessment procedures using data collected from an actual structure tested in the laboratory. The procedures outlined in FEMA-356, EC8 and TEC-2007 are applied to a full-size, three-story, non-symmetric reinforced concrete building tested at the ELSA laboratory at JRC/Ispra under the SPEAR project. For this purpose, a 3D analytical model of the building is subjected to the records used in the experimental phase and deformation demands are computed according to the procedures described in the guidelines that are being assessed for their correctness. The performance of the structure is evaluated at member level and the accuracy of the considered procedures is rated through comparisons with measurements and observations made after the experiments. The study indicates that the main difference between the procedures stem from different performance-based limit values and the characterizing phrases that are used to qualify them. It appears necessary that a harmonization should be agreed upon before universal application of these procedures. Otherwise the conflicting acceptability criteria among different procedures are likely to create confusion among engineers [24].

Chapter II

2. GENERAL PRINCIPLES AND RULES OF EARTHQUAKE DESIGN

2.1. Overview

In chapter 2, the definition of seismic loads and analysis requirements to be applied to earthquake resistance structures according to EC8 and TEC-2007, are explained.

2.1. General Rules and Principles

2.1.1. General Rules of EC8

Structures in seismic regions shall be designed and constructed in such a way that the following fundamental requirements are met:

- No-collapse requirements: the structure shall be designed and constructed to withstand the seismic design action without local or global collapse, thus retaining its structural integrity and residual load bearing capacity after seismic events.
- Damage limitation requirements: the structure shall be designed and constructed to withstand a seismic action having a larger probability of occurrence than the design seismic action, without the occurrence of damage.

In order to satisfy the fundamental requirements of seismic design stated in EC8, the following limit states should be checked:

- Ultimate limit states: are those associated with collapse or with other forms of structural failure which might endanger the safety of people.
- Damage limitation states: are those associated with damage beyond which specified service requirements are no longer met.

2.1.2. General Rules of TEC-2007

The general principle of earthquake resistant design to this specification, is to prevent structural or non-structural elements of buildings from any damage in low intensity earthquakes, to limit the damage in structural and non-structural elements to repairable levels in medium-intensity earthquakes, and to prevent the overall or partial collapse of buildings in high intensity earthquake in order to avoided the loss of life.

The design earthquake considered in this specification corresponds to high intensity defined above.

For buildings with building importance factor of I=1 in accordance with Table 2.1, the probability of exceedance of the design earthquake within a period of 50 years is 10%.

Table 2.1 Building Importance Factor [20].

Purpose of Occupancy or Type of Building	Importance Factor (I)
1. Buildings required to be utilized after the earthquake and buildings containing hazardous materials a) Buildings required to be utilized immediately after the earthquake (Hospitals, dispensaries, health wards, firefighting buildings and facilities, PTT and other telecommunication facilities, transportation stations and terminals, power generation and distribution facilities; governorate, county and municipality administration buildings, first aid and emergency planning stations) b) Buildings containing or storing toxic, explosive and flammable materials, etc.	1.5
2. Intensively and long-term occupied buildings and buildings preserving valuable goods a) Schools, other educational buildings and facilities, dormitories and hostels, military barracks, prisons, etc. b) Museums	1.4
3. Intensively but short-term occupied buildings Sport facilities, cinema, theatre and concert halls, etc.	1.2
4. Other buildings Buildings other than above defined buildings. (Residential and office buildings, hotels, building-like industrial structures, etc.)	1.0

The building structural system resisting seismic loads as a whole as well as each structural element of the system shall be provided with sufficient stiffness, stability and strength to ensure an uninterrupted and safe transfer of seismic loads down to the foundation soil. It is essential that floor systems possess sufficient stiffness and strength to ensure the safe transfer of lateral seismic loads between the elements of the structural system. In insufficient cases, appropriate transfer elements shall be arranged on floors.

2.2. Ground Conditions

2.2.1. Ground Conditions According to EC8

According to EC8, there are five kinds of ground types are described by the stratigraphic profiles and parameter which is given in table 2.2.

Table 2.2 Ground Types [19].

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30m)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5m of weaker material at the surface.	> 800	-	-
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium dense sand gravel or stiff clay with thickness from several tens to many hundreds of meters.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesion less soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5m and 20m, underlain by stiffer material with v_s > 800 m/s.	-	-	-
S_1	Deposits consisting, or containing a layer at least 10m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	-	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1	-	-	-

The site should be classified according to the value of the average shear wave velocity ($v_{s,30}$) if this is available. Otherwise the value of standard penetration test (N_{SPT}) should be used.

For sites with ground conditions matching either one of the two special ground types S_1 or S_2, special studies for the definition of the seismic action are required. For these types, and particularly for S_2, the possibility of soil failure under the seismic action shall be taken into account.

2.2.2. Ground Conditions According to TEC-2007

Soil types to be considered according to TEC-2007 to represent the most common local soil conditions are given in Table 2.3. The soil parameters defined in this table should be considered as standard values for guidance only in determining the soil type.

Local site classes to be considered as the bases of determination of local soil conditions are given in Table 2.4.

Soil investigations based on appropriate site and laboratory tests are mandatory and should be conducted for all buildings with a total height exceeding 60 m in the first and second seismic zones and for buildings with importance factor, I=1.5 and I=1.4 in all seismic zones. Regarding the buildings other than those defined above, in the first and second seismic zones, available local information or inspection results shall be included or published references shall be quoted in the seismic analysis reports to identify the soil groups and local site classes in accordance with table 2.3 and Table 2.4, in addition to these requirements in all seismic zones, group (D) soils according to Table 2.3 with water table less than 10 m from the soil surface shall be investigated and the results shall be documented to identify whether liquefaction potential exists, by using appropriate analytical methods based on in-situ and laboratory tests.

Table 2.3 Soil Groups [20].

Soil Group	Description of Soil Group	Standard Penetration (N/30)	Relative Density (%)	Unconfined Compressive Strength (kPa)	Drift Wave Velocity (m / s)
(A)	1. Massive volcanic rocks, un weathered sound metamorphic rocks, stiff cemented sedimentary rocks	-	-	>1000	>1000
	2. Very dense sand, gravel	> 50	85-100	-	>700
	3. Hard clay and silty clay	> 32	-	> 400	> 700
(B)	1. Soft volcanic rocks such as tuff and agglomerate, weathered cemented sedimentary rocks with planes of discontinuity	-	-	500-1000	700-1000
	2. Dense sand, gravel	30-50	65-85	-	400-700
	3. Very stiff clay, silty clay	16-32	-	200-400	300-700
(C)	1. Highly weathered soft metamorphic rocks and cemented sedimentary rocks with planes of discontinuity	-	-	< 500	400-700
	2. Medium dense sand and gravel	10-30	35-65	-	200-400
	3. Stiff clay and silty clay	-	-	100-200	200-300
(D)	1. Soft, deep alluvial layers with high ground water level	-	-	-	< 300
	2. Loose sand.	< 10	< 35	-	< 200
	3. Soft clay and silty clay	< 8	-	< 100	< 200

Table 2.4 Local Site Classes [20].

Local Site Class	Soil Group according to Table 2.2 and Topmost Soil Layer Thickness (h1)
Z1	Group (A) soils. Group (B) soils with h1 $\leq$ 15m
Z2	Group (B) soils with h1 > 15m. Group (C) soils with h1 $\leq$ 15m
Z3	Group (C) soils with 15 m < h1 $\leq$ 50m. Group (D) soils with h1 $\leq$ 10m
Z4	Group (C) soils with h1 > 50 m. Group (D) soils with h1 > 10m
Notes: In the case where the thickness of the topmost soil layer under the foundation is less than 3 m, the layer below may be considered as the topmost soil layer indicated in this Table.	

2.3. Seismic Design

2.3.1. Definition of Seismic Action According to EC8

National territories shall be subdivided by National Authorities into seismic zones, depending on the local hazard. The hazard is described in terms of a single parameter, the value of the reference peak ground acceleration on type A ground, a_{gR}. By definition, the hazard within each zone is assumed to be constant.

The reference peak ground acceleration (a_{gR}), chosen by the National Authorities for each seismic zone, corresponds to the reference return period T_{NCR} of the seismic action for no-collapse requirement (or equivalently the reference probability of exceedance in 50 years, P_{NCR}) chosen by the National Authorities. An importance factor γ_I equal to 1.0 is assigned to this reference return period. For return periods other than the reference, the design ground acceleration on type A ground a_g is equal to a_{gR} times the importance factor γ_I ($a_g = \gamma .\ a_{gR}$). Earthquake motion at a given point on the surface is represented by an elastic ground acceleration response spectrum, henceforth called an "elastic response spectrum".

Horizontal elastic response spectrum: As seen in figure 2.1, The elastic response spectrum $S_e(T)$ is defined by the following expressions, for the horizontal components of seismic action:

$$S_e(T) = a_g \,.\, S \,.\, \left[1 + \frac{T}{T_B} . (\eta . 2.5 - 1)\right] \qquad (0 \leq T \leq T_B) \qquad (2.1)$$

$$S_e(T) = a_g \,.\, S .\, \eta .\, 2.5 \qquad (T_B \leq T \leq T_c) \qquad (2.2)$$

$$S_e(T) = a_g \,.\, S .\, \eta .\, 2.5 \left[\frac{T_C}{T}\right] \qquad (T_c \leq T \leq T_D) \qquad (2.3)$$

$$S_e(T) = a_g \,.\, S .\, \eta .\, 2.5 \left[\frac{T_C T_D}{T^2}\right] \qquad (T_D \leq T \leq 4s) \qquad (2.4)$$

in which;

$S_e(T)$: Elastic response spectrum.

T : Vibration period of a linear single-degree-of-freedom system.

a_g : Design ground acceleration on type A ground.

T_B : Lower limit of the period of the constant spectral acceleration branch.

T_C : Upper limit of the period of the constant spectral acceleration branch.

T_D : Value defining the beginning of the constant displacement response range of The spectrum.

S : Soil factor.

η : Damping correction factor with a reference value of η=1 for 5% viscous damping.

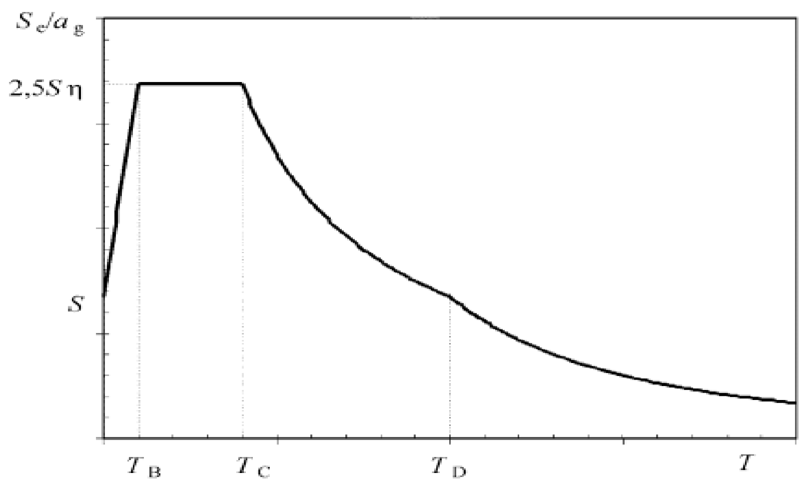


Figure 2.1 Elastic Response Spectrums [19].

The values of the periods T_B, T_C and T_D and of the soil factor S describing the shape of the elastic response spectrum depend upon the ground type. The values of parameters, T_B, T_C, T_D and S for each ground type and type (shape) of spectrum to be used in a country may be found in its National Annex. If the earthquakes that contribute most to the seismic hazard defined for the site for the purpose of probabilistic hazard assessment have a surface-wave magnitude, M_s, not greater than 5.5, it is recommended that the Type 2 spectrum is adopted. For the five ground types A, B, C, D and E the recommended values of the parameters S,

T_B, T_C and T_D are given in table 2.5 for the type 1 spectrum and in table 2.6 for the type 2 spectrum. Figure 2.2 and Figure 2.3 show the shapes of the recommended type 1 and type 2 spectra, respectively, normalized by a_g, for 5% damping.

Table 2.5 Type 1 Elastic Response Spectra [19].

Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1	0.15	0.4	2.0
B	1.2	0.15	0.5	2.0
C	1.15	0.20	0.6	2.0
D	1.35	0.20	0.8	2.0
E	1.4	0.15	0.5	2.0

Table 2.6 Type 2 Elastic Response Spectra [19].

Ground type	S	T_B (s)	T_C (s)	T_D (s)
A	1	0.05	0.4	1.2
B	1.35	0.05	0.5	1.2
C	1.5	0.10	0.25	1.2
D	1.8	0.10	0.30	1.2
E	1.6	0.05	0.25	1.2

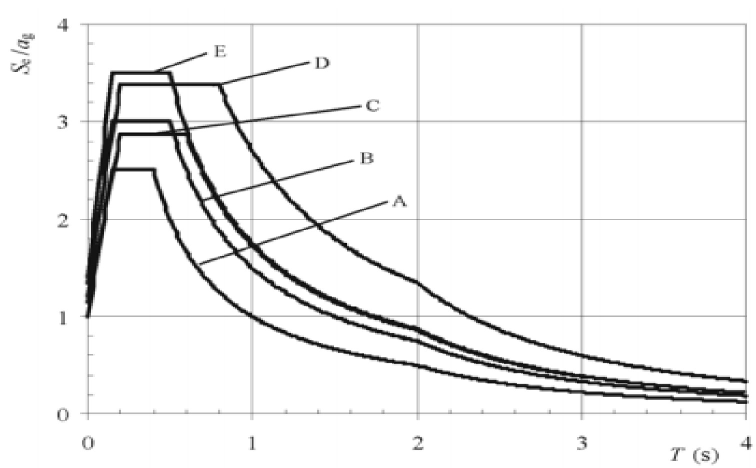


Figure 2.2 Type 1 Elastic Response Spectra for Ground Types A to E 5% damping [19].

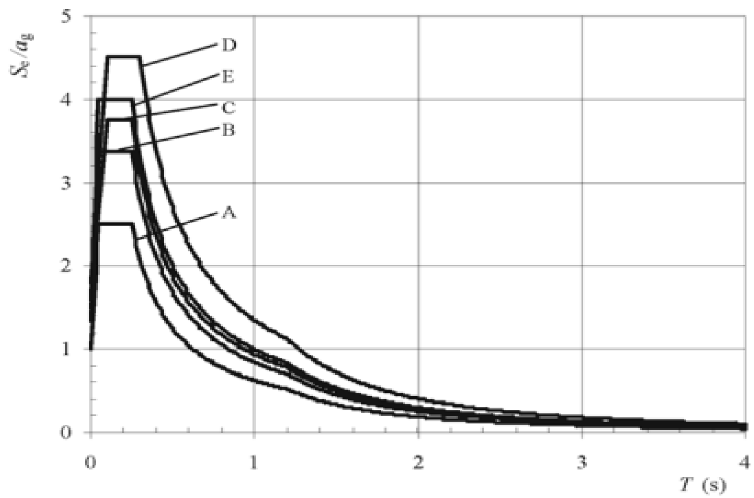


Figure 2.3 Type 2 Elastic Response Spectra for Ground Types A to E 5% damping [19].

The value of the damping correction factor (η) may be determined by the following expression:

$$\eta = \sqrt{10/(5+\xi)} \geq 0.55 \qquad (2.5)$$

where;

ξ : Viscous damping ratio of the structure, expressed as a percentage.

The elastic displacement response spectrum, $S_{De}(T)$, shall be obtained by direct transformation of the elastic acceleration response spectrum $S_e(T)$, using the following expression:

$$S_{De}(T) = S_e(T)\left[\frac{T}{2\pi}\right]^2 \qquad (2.6)$$

Expression (2.6) should normally be applied for vibration periods not exceeding 4.0 second. For structures with vibration periods longer than 4.0 second, a more complete definition of the elastic displacement spectrum is possible.

Vertical elastic response spectrum: the vertical component of the seismic action shall be represented by elastic response spectrum, S_{ve}, derived using expressions (2.7) to (2.10).

$$S_{ve}(T) = a_{vg} \cdot [1+ \frac{T}{T_B} \cdot (\eta \cdot 3.0 - 1)] \qquad (0 \le T \le T_B) \qquad (2.7)$$

$$S_{ve}(T) = a_{vg} \cdot \eta \cdot 3.0 \qquad (T_B \le T \le T_c) \qquad (2.8)$$

$$S_{ve}(T) = a_{vg} \cdot \eta \cdot 3.0 \left[\frac{T_C}{T}\right] \qquad (T_c \le T \le T_D) \qquad (2.9)$$

$$S_{ve}(T) = a_{vg} \cdot \eta \cdot 3.0 \left[\frac{T_C T_D}{T}\right]^2 \qquad (T_D \le T \le 4\mathrm{s}) \qquad (2.10)$$

The values to be ascribed to T_B, T_C, T_D and a_{vg} for each type (shape) of vertical spectrum to be used in a country may be found in its National Annex. The recommended choice is the use of two types of vertical spectra Type 1 and Type 2. As for the spectra defining the horizontal components of the seismic action, if the earthquakes that contribute most to the seismic hazard defined for the site for the purpose of probabilistic hazard assessment have a surface-wave magnitude, M_s, not greater than 5.5, it is recommended that the Type 2 spectrum is adopted. For the five ground types A, B, C, D and E the recommended values of the parameters describing the vertical spectra are given in Table 2.8. These recommended values do not apply for special ground types S_1 and S_2.

Table 2.7 Vertical Elastic Response Spectra [19].

Spectrum	a_{vg} / a_g	T_B (s)	T_c (s)	T_D (s)
Type A	0,90	0,05	0,15	1,0
Type B	0,45	0,05	0,15	1,0

Design spectrum this reduction is accomplished by introducing the behavior factor *q*. The behavior factor *q* is an approximation of the ratio of the seismic forces that the structure would experience if its response was completely elastic with 5% viscous damping, to the seismic forces that may be used in the design, with a conventional elastic analysis model, still ensuring a satisfactory response of the structure. The value of the behavior factor q may be different in different horizontal directions of the structure, although the ductility classification shall be the same in all directions.

For the horizontal components of the seismic action the design spectrum, $S_d(T)$, shall be defined by the following expressions:

$$S_d(T) = a_g.S.\left[\frac{2}{3} + \frac{T}{T_B} \cdot \left(\frac{2.5}{9} - \frac{2}{3}\right)\right] \qquad (0 \leq T \leq T_B) \qquad (2.11)$$

$$S_d(T) = a_g\ .S.\ \frac{2.5}{q} \qquad (T_B \leq T \leq T_C) \qquad (2.12)$$

$$S_d(T) = \begin{cases} a_g\ .S.\ \frac{2.5}{q}\left[\frac{T_C}{T^2}\right] \\ \geq \beta\ .\ a_g \end{cases} \qquad (T_B \leq T \leq T_C) \qquad (2.13)$$

$$Sd(T) = \begin{cases} a_g\ .S.\ \frac{2.5}{q}\left[\frac{T_C T_D}{T^2}\right] \\ \geq \beta\ .\ a_g \end{cases} \qquad (T_D \leq T) \qquad (2.14)$$

where;

a_g, S, T_C and T_D are as defined in the equations before.

$S_d\,(T)$: Design spectrum.

q : Behavior factor.

β : Lower bound factor for the horizontal design spectrum.

For the vertical component of the seismic action the design spectrum is given by expressions (2.11) to (2.14), with the design ground acceleration in the vertical direction, a_{vg} replacing a_g, S taken as being equal to 1.0.

For the vertical component of the seismic action a behavior factor q up to 1.5 should generally be adopted for all materials and structural systems.

The adoption of values for q greater than 1.5 in the vertical direction should be justified through an appropriate analysis.

Buildings are classified into four importance classes (γ_I), depending on the consequences of collapse for human life, on their importance for public safety and civil protection in the immediate post-earthquake period and on the social consequences of collapse. The recommended values of γ_I for importance classes are given in table 2.8.

Table 2.8 Values of γ_I for Important Classes [19].

Importance classes	Buildings	The recommended value of γ
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.	0.8
II	Ordinary buildings, not belonging in the other categories.	1.0
III	Building whose seismic resistance is importance in view of the consequence associated with a collapse, e.g. school, assembly halls, cultural institutions etc.	1.2
IV	Building whose integrity during earthquakes is of vital importance for civil protection, hospitals, fire stations, power plants, etc.	1.4

2.3.1. Definition of Seismic Action According to TEC-2007:

The spectral acceleration coefficient A (T), which shall be considered as the basis for the determination of seismic loads is given by equation (2.15). The elastic spectral acceleration S_{ae} (T), which is defined as ordinate of elastic acceleration spectrum defined for 5% damped rate, elastic acceleration spectrum is equal to spectrum acceleration coefficient times the acceleration of gravity, g, as given by equation (2.16).

$$A(T) = A_0\, I\, S(T) \tag{2.15}$$

$$S_{ae}(T) = A(T)\, g \tag{2.16}$$

where:

A_0 : Effective ground acceleration coefficient.

I : Building importance factor.

$S(T)$: Spectrum coefficient.

g : Gravitational acceleration (9.81 m/s^2).

The effective ground acceleration coefficient (A_0), appearing in Equation (2.15) is specified in Table 2.9.

Table 2.9 Effective Ground Acceleration Coefficient [20].

Seismic Zone	A_0
1	0.4
2	0.3
3	0.2
4	0.1

The building importance factor, I, given in Equation (2.15) is stated in Table 2.1.

The spectrum coefficient $S(T)$, given in Equation (2.10) shall be determined by Equation (2.11), depending on the local site conditions and the building natural period, T.

$$S(T) = 1 + 1.5\,\frac{T}{T_A} \qquad (0 \le T \le T_A) \tag{2.17}$$

$$S(T) = 2.5 \qquad (T_A \le T \le T_B) \tag{2.18}$$

$$S(T) = 2.5\left[\frac{T_B}{T}\right]^{0.8} \qquad (T_B < T) \tag{2.19}$$

Spectrum characteristic periods, T_A and T_B, are specified in Table 2.10, depending on local site classes defined in Table 2.5.

Table 2.10 Spectrum characteristic Periods [20].

Local Site Class	T_A (second)	T_B (second)
Z1	0.10	0.30
Z2	0.15	0.40
Z3	0.15	0.60
Z4	0.20	0.90

In case where the requirements specified before are not met, spectrum characteristic periods defined in Table 2.10 for local site class Z4 shall be used.

In required cases, elastic acceleration spectrum may be determined through special investigations by considering local seismic and site conditions. However spectral acceleration coefficients corresponding to so obtained acceleration spectrum ordinates shall in no case be less than those determined by Equation (2.10) based on relevant characteristic periods specified in Table 2.11.

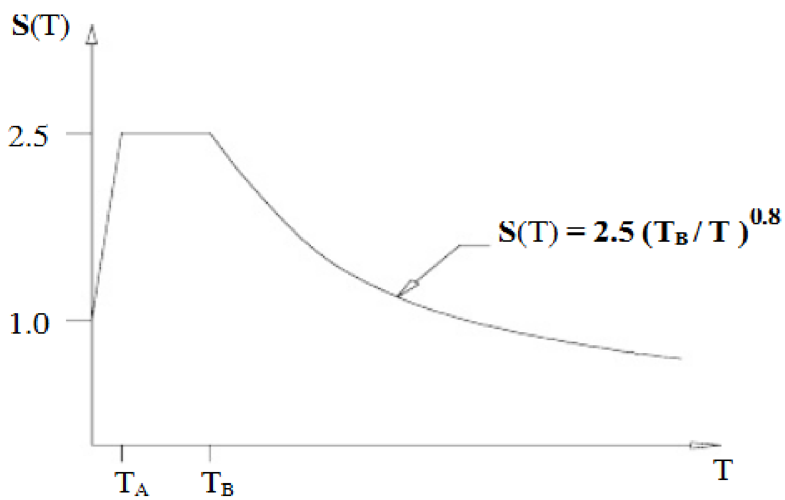


Figure 2.4 Design Acceleration Spectrums [20].

In order to consider the specific nonlinear behavior of the structural system during earthquake, elastic seismic loads to be determined in terms of spectral acceleration coefficient shall be divided to below defined Seismic Load Reduction Factor to account for. Seismic Load Reduction Factor, shall be determined by Equations (2.20) or (2.21) in terms of Structural System Behavior Factor, R, defined in Table 2.11 for various structural systems, and the natural vibration period T.

$$R\mathrm{a}(T) = 1.5 + (R\text{-}1.5)\,\frac{T}{T_A} \qquad (0 \leq T \leq T_A) \qquad (2.20)$$

$$R\mathrm{a}(\mathrm{T}) = R \qquad (T_A < T) \qquad (2.21)$$

Table 2.11 Structural Systems Behavior Factors [20].

BUILDING STRUCTURAL SYSTEM	Systems of Nominal Ductility Level	Systems of High Ductility Level
1. CAST-IN-SITE REINFORCED CONCRETE BUILDINGS		
1.1. Buildings in which seismic loads are fully resisted by frames………	4	8
1.2. Buildings in which seismic loads are fully resisted by coupled structural walls ……………………………………………………….........	4	7
1.3. Buildings in which seismic loads are fully resisted by solid structural walls …………………………………………........................	4	6
1.4. Buildings in which seismic loads are jointly resisted by frames and solid and / or coupled structural walls ………………………………...	4	7
2. PREFABRICATED REINFORCED CONCRETE BUILDINGS		
2.1. Buildings in which seismic loads are fully resisted by frames with connections capable of cyclic moment transfer…………………………..	3	7
2.2. Single-storey buildings in which seismic loads are fully resisted by columns with hinged upper connections ………………………………...	-	3
2.3. Prefabricated buildings with hinged frame connections in which seismic loads are fully resisted by prefabricated or cast – in – situ solid structural walls and / or coupled structural walls………………………....	-	5
2.4. Buildings in which seismic loads are jointly resisted by frames with connections capable of cyclic moment transfer and cast-in-situ solid and / or coupled structural walls ……………………………………………..	3	6
3. STRUCTURAL STEEL BUILDINGS		
3.1. Buildings in which seismic loads are fully resisted by frames ……..	5	8
3.2. Single – storey buildings in which seismic loads are fully resisted by columns with connections hinged at the top …………………………	-	4
3.3. Buildings in which seismic loads are fully resisted by braced frames or cast-in-situ reinforced concrete structural walls		
a- Centrically braced frames ……………...	4	5
b- Eccentrically braced frames ………………………………………..	-	7
c- Reinforced concrete structural walls...	4	6
3.4. Buildings in which seismic loads are jointly resisted by structural steel braced frames or cast-in-situ reinforced concrete structural walls		
a- Centrically braced frames...	5	6
b- Eccentrically braced frames...	-	8
c- Reinforced concrete structural walls...	4	7

2.3.3. Definition of Load Combination According to EC8

The design value E_d of the effects of actions in the seismic design situation shall be determined in accordance with the following combination:

$$E_d = \sum G_{kj} + \gamma\, A_{Ed} + \sum \psi_{2i}\, Q_{ki} \qquad (2.20)$$

where;

γ_I : Importance factor as seen in table 2.6.

G_{kj} : Characteristic value of dead loads.

A_{Ed} : Design value of return period of specific earthquake motion;

ψ_{2i} : Combination coefficient of live load.

Q_{ki} : Characteristic value of live load.

The inertia effects of the design seismic action shall be evaluated by taking into account the presence of the masses associated with all gravity loads appearing in the following combination of action.

$$E_d = \sum G_{kj} + \gamma\, A_{Ed} + \sum \psi_{2i}\, Q_{ki} \qquad (2.21)$$

where;

$\Psi_{E,i}$: The combination coefficient for variable action *I*.

2.3.3. Definition of Load Combination According to TEC-2007

The design value E_d of the effects of action in the seismic design situation shall be determined in accordance with the following combination:

$$E_d = G + Q \pm E_x \pm 0.3E_y \qquad (2.22)$$

$$E_d = G + Q \pm E_y \pm 0.3E_x \qquad (2.23)$$

where;

G : Dead load

Q : Live load

E_x, E_y : Earthquake in direction to x and y.

Or in the case of unfavorable result,

$$E_d = 0.9G + Q \pm E_n \pm 0.3E_y \quad (2.24)$$

$$E_d = 0.9G + Q \pm E_y \pm 0.3E_n \quad (2.25)$$

The seismic weight of the structure shall be determined by given equation:

$$W = \sum g_{i,N} + \sum n\, q_{i,N} \quad (2.26)$$

Where;

g_i : Total live load at i'th storey of the building.

q_i : Total dead load at i'th storey of the building.

n : Live load participation factor.

N : Number of stories in the structure.

Live load participation factor (*n*) is given in table 2.12. In industrial buildings, n=1 shall be taken. In the calculation of roof weight for seismic load, 30% of snow load shall be considered.

Table 2.12 Live Load Participation Factors [20].

Purpose of Occupancy of Building	*N*
Depot, warehouse, etc.	0.8
School, dormitory, sport facility, cinema, car park, restaurant, shop, etc.	0.6
Residence, office, hotel, hospital, etc.	0.30

Chapter III

3. GENERAL RULES OF EARTHQUAKE RESISTANT STRUCTURAL SYSTEM

3.1. Overview

This chapter covers the general rules of design criteria of the building according to EC8 and TEC-2007, to avoid unwanted behavior of building during the seismic events.

3.2. Criteria for Structural Regularity According to EC8

According to EC8, there are two types of design building criteria should be achieved as possible, which are for regularity in plan and in elevation.

3.2.1. Criteria for Regularity in Plan

According to EC8 a building to be considered as being regular in plan, it shall satisfy all the conditions below:

- With respect to the lateral stiffness and mass distribution, the building structure shall be approximately symmetrical in plan with respect to two orthogonal axes.
- The plan configuration shall be compact.
- The in-plan stiffness of the floors shall be sufficiently large in comparison with the lateral stiffness of the vertical structural elements, so that the deformation of the floor shall have a small effect on the distribution of the forces among the vertical structural elements.
- The slenderness $\lambda = L_{max} / L_{min}$ of the building in plan shall be not higher than 4, where L_{max} and L_{min} are respectively the larger and smaller in plan dimension of the building, measured in orthogonal directions.

- At each level and for each direction of analysis x and y, the structural eccentricity (e_o) and the torsional radius r shall be in accordance with the two conditions below, which are expressed for the direction of analysis y:

$$e_{ox} \leq 0.3 \, . \, r_{\mathrm{x}} \tag{3.3.a}$$

$$r_x \geq l_s \tag{3.3.b}$$

where;

e_{ox} : Distance between the center of stiffness and the center of mass, measured along the x direction, which is normal to the direction of analysis considered.

r_x : Square root of the ratio of the torsional stiffness to the lateral stiffness in the y direction ("torsional radius").

l_s : Radius of gyration of the floor mass in plan (square root of the ratio of (a) the polar moment of inertia of the floor mass in plan with respect to the center of mass of the floor to (b) the floor mass).

3.2.2. Criteria for Regularity in Elevation

Building to be considered as being regular in elevation, it shall satisfy all the conditions below:

- All lateral load resisting systems, such as cores, structural walls, or frames, shall run without interruption from their foundations to the top of the building or, if setbacks at different heights are present, to the top of the relevant zone of the building.
- Both the lateral stiffness and the mass of the individual stories shall remain constant or reduce gradually, without abrupt changes, from the base to the top of a particular building.
- In framed buildings the ratio of the actual stories resistance to the resistance required by the analysis should not vary disproportionately between adjacent stories.

3.3. Criteria for Structural Regularity According to TEC-2007

Regarding the definition of irregular buildings whose design and construction should be avoided because of their unfavorable seismic behavior. There are two general types of building irregularities, where types of irregularities in plan called "A-type irregularities" and in elevation called "B-types irregularities" are given in "Table 2.1" from TEC-2007, and their relevant conditions as given below.

3.3.1. Criteria for Regularity in Plan

A1-Torsional Irregularity

The first type of irregularity in TEC-2007 is "Torsional Irregularity". It is also called "A1-type irregularity". Torsion in a building is caused by asymmetrical distribution of rigidity. The case where Torsional Irregularity Factor, η_{bi}, which is defined for any of the two orthogonal earthquake directions as the ratio of the maximum storey drift at any storey to the average storey drift at the same storey in the same direction, is greater than 1.2, as shown in figure 3.1.

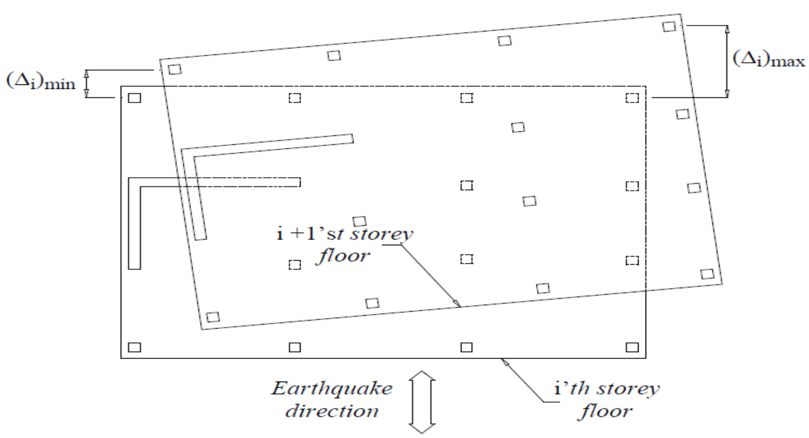


Figure 3.1 Type A1- Torsional Irregularity [20].

In the case where floors behave as rigid diaphragms in their own planes:

$$\eta_{bi} = (\Delta_i)_{max} / (\Delta_i)_{ort} > 1.2 \tag{3.1}$$

$$(\Delta_i)_{ave} = 1/2\ [(\Delta_i)_{max} + (\Delta_i)_{min}] \tag{3.2}$$

where;

η_{bi} : Torsional irregularity factor defined at i'th storey of the building.

$(\Delta_i)_{ave}$: Average storey drift of i'th storey of the building.

$(\Delta_i)_{max}$: Maximum storey drift of i'th storey of the building.

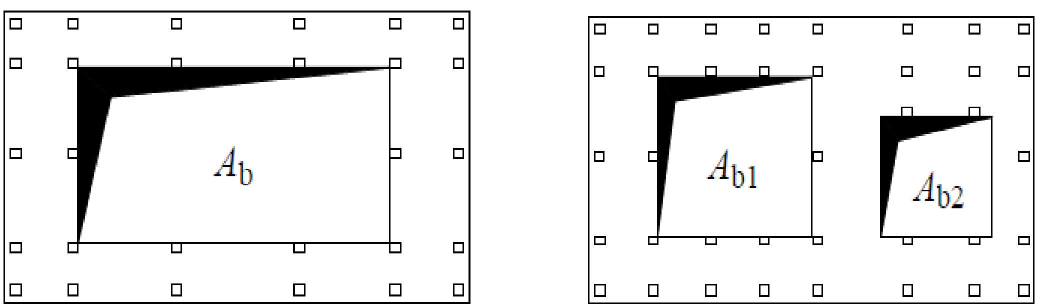
$(\Delta_i)_{min}$: Minimum storey drift of i'th storey of the building.

Storey drifts shall be calculated by considering the effects of ± %5 additional eccentrics.

A2-Floor Discontinuities

The second type of irregularity is "Floor Discontinuities" which is also called " A2-type irregularity". There are three cases where floor discontinuity irregularities occur in any floor as explained:

- The case where the total area of the openings including those of stairs and elevator shafts exceeds 1/3 of the gross floor area, as shown in figures 3.2.a and 3.2.b.



(a) Type A2-Irregularity-I (b) Type A2-Irregularity-I

Figure 3.2 Type A2- Floor Discontinuity Cases I [20].

$$Ab = Ab_1 + A_{b2} \tag{3.2}$$

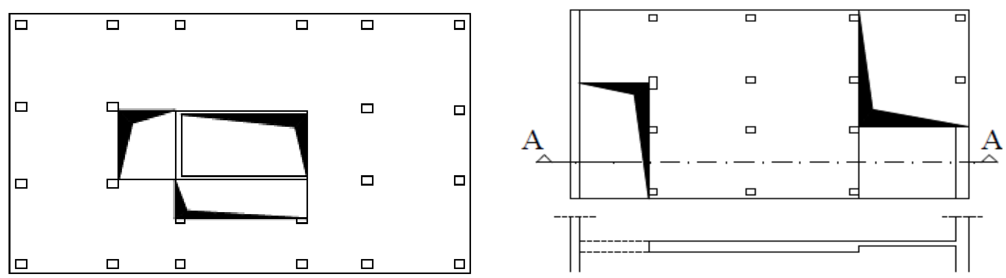
$$Ab / A > 1/3 \tag{3.3}$$

where;

A_b : Total area of openings

A : Gross floor area

- The cases where local floor openings make it difficult the safe transfer of seismic loads to vertical structural elements, as shown in figure 3.3.



(a) Type A2 -Irregularity-II (b) Type A2 -Irregularity-III

Figure 3.3 Type A2- Floor Discontinuity Cases II [20].

- The cases of abrupt reductions in the in-plane stiffness and strength of floors.

A3- Projections in Plan

It is the third type of irregularity and also called "A3-type of irregularity". The cases where projections beyond the re-entrant corners in both of the two principal directions in plan exceed the total plan dimensions of the building in the respective directions by more than 20%. There are three drawings explaining this irregularity as shown below:

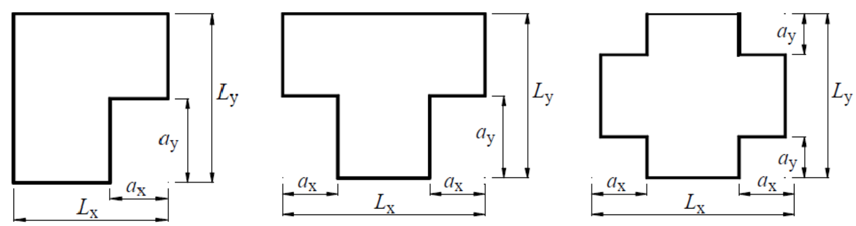


Figure 3.4 Type A3- Irregularity [20].

$$a_x > 0.2\ L_x \tag{2.4. a}$$

$$a_y > 0.2\ L_y \tag{2.4.b}$$

where;

Lx, Ly : Length of the building at x, y direction

a_y, a_x : Length of re-entrant corners in x, y direction

3.3.2. Criteria for regularity in Elevations

B1- Interstorey Strength Irregularity (Weak Storey).

It is also called "B1-type of irregularity" in TEC-2007. In reinforced concrete buildings, the case where in each of the orthogonal earthquake directions, Strength Irregularity Factor η_{ci}, which is defined as the ratio of the effective shear area of any story to the effective shear area of the story immediately above, is less than 0.80. B1-type of irregularity commonly exist in the ground floors of the commercial buildings.

$$[\eta_{ci} = (\Sigma A_e)_i \, / \, (\Sigma A_e)_i+1 < 0.80] \quad (3.5)$$

where;

A_e : Effective shear area.

For B1-type of irregularity, there is not any drawing in the regulations.

Definition of effective shear area in any storey:

$$\Sigma A_e = \Sigma A_w + \Sigma A_g + 0.15 \, \Sigma A_k \quad (3.6)$$

where;

A_w : Effective of web area of column cross sections.

A_g : Section areas of structural elements at any storey.

A_k : Infill wall areas.

B2- Interstorey Stiffness Irregularity (Soft Storey)

It is called "B2-Type of irregularity" in TEC-2007. The case where in each of the two orthogonal earthquake directions, stiffness irregularity factor η_{ki} , which is defined as the ratio of the average storey drift at any storey to the average storey drift at the storey immediately above or below, is greater than 2.0. as shown in the expression (2.7.a) and (2.7.b) :

$$\eta_{ki} = (\Delta_i/h_i)_{ave} \, / \, (\eta_{i+1}/h_{i+1})_{ave} > 2.0 \quad (2.7.a)$$

$$\eta_{ki} = (\Delta_i \, /h_i)_{ave} \, / \, (\Delta_{i\,-1}/h_{i-1})_{ave} > 2.0 \quad (2.7.b)$$

where:

η_{ki} : Stiffness irregularity factor defined at i'th storey of the building.

Δ_i : Storey drift of i'th storey of the building.

h_i : Height of i'th storey of building [m].

Storey drifts shall be calculated, by considering the effects of ±%5 additional eccentricities.

B3-Discontinuity of Vertical Structural Elements

It is called "B3- type of irregularity" in the TEC-2007. The cases where vertical structural elements (columns or structural walls) are removed at some stories and supported by beams or gusseted columns underneath, or the structural walls of upper stories are supported by columns or beams underneath, as shown in figure 3.5.

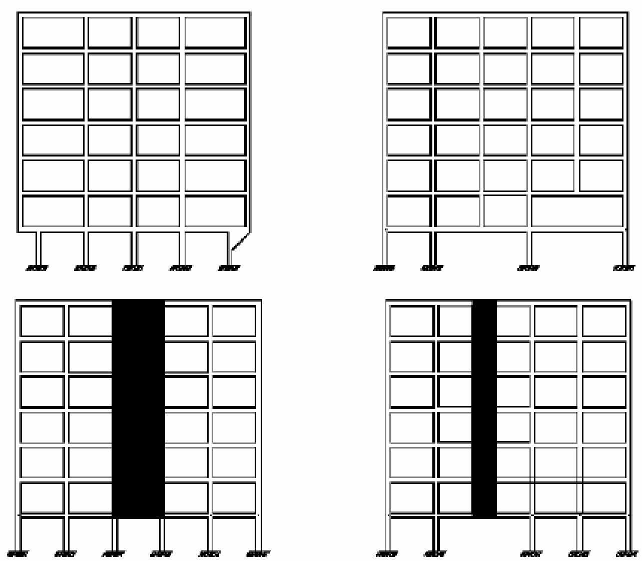


Figure 3.5 Type B3- Discontinuities of Vertical Structural Elements [20].

Article 2.3.2.4 in TEC-2007 regulations, defines these items which are shown in figure 3.5.

Chapter IV

4. SPECIAL DESIGN RULES FOR REINFORCED CONCRETE BUILDINGS

4.1. Overview

In this chapter the materials conditions, geometric conditions and reinforcement conditions for reinforced concrete building elements according to EC8 and TEC-2007, are explained.

In EC8, the reinforced concrete building elements are divided into three types according to their ductility level; low ductility (DCL), medium ductility (DCM) and high ductility level (DCH). For DCL building elements are not preferred to use in region with seismic risk.

In TEC-2007, the reinforced concrete building elements are divided into two types according to their ductility level; high ductility building level (HDL), nominal ductility level (NDL).

4.2. Material Conditions

4.2.1. Material Conditions According to EC8

In primary seismic elements of reinforced concrete building the following material conditions shall be used:

- For DCM reinforced concrete elements, concrete class lower than C16/20 class and for DCH reinforced concrete elements concrete class lower than C20/25, shall be not be used.
- With exception of close stirrups and cross-ties only, in critical regions deformed bars shall be used as reinforcing steel.
- For DCM reinforced concrete elements, reinforcing steel of class B or C shall be used and for DCH reinforced concrete elements, reinforcing steel C shall be used, in critical

regions of primary seismic element as shown table 4.1. This shows the properties of reinforcing steel classes according to Eurocode 2.

Table 4.1 Properties of Reinforcement [25].

Product form	**Bars and de-coiled rods**			**Wire Fabrics**			**Requirement or quintile value (%)**
Classes	A	B	C	D	E	F	-
Characteristic yield strength f_{yk} or $f_{0.2k}$ (*MPa*)	400 to 600						5.0
Minimum value of $k = (f_t/f_y)_k$	≥1.05	≥1.08	≥1.15 <1.35	≥1.05	≥1.08	≥1.15 <1.35	10.0
Characteristic strain at maximum force, ε_{uk} (%)	≥2.5	≥5.0	≥7.5	≥2.5	≥5.0	≥7.5	10.0
Bendability	Bend/Rebind test			-			
Shear strength	-			0,3 $A\ f_{yk}$ (*A* is area of wire)			Minimum
Maximum deviation from nominal mass (individual bar or wire) (%) — Nominal bar size (mm) ≤8 >8	± 6.0 ± 4.5						5.0

Note: The values for the fatigue stress range with an upper limit of $\beta\ f_{yk}$ and for the Minimum relative rib area for use in a Country may be found in its National Annex.

- For DCM reinforced concrete elements, welded wire meshes may be used if meet the design requirements.

4.2.2. Material Conditions According to TEC-2007

For all reinforced concrete buildings to be built in seismic zones, the following material conditions shall be used:

- Concrete with strength lower than C20 shall be not be used. It should satisfy the quality control requirements specified in Turkish standard (TS-500).
- Unribbed reinforcement steel cannot be used exempt hoops and crossties with flooring reinforcement.
- Reinforcing steel more than S420 shall not be used in reinforced concrete structural elements, with the exception of specific elements may be used in in flat slabs, in the

slabs of joist floors, in peripheral external walls of basements, in the webs of structural walls of buildings in which entire seismic loads are resisted by such walls of full building height satisfying both of the conditions given by equations (4.1) and (4.2) below:

$$\sum A_g / \sum A_p \geq 0.002 \tag{4.1}$$

$$V_t / \sum \mathrm{A_g} \leq 0.5\, f_{ctd} \tag{4.2}$$

where:

A_g : Gross section area of column or wall end zone.

A_p : Plane area of story building.

V_t : Total seismic load acting on a building.

f_{ctd} : Design tensile strength of concrete.

4.3. Geometric Conditions

4.3.1. Geometric Conditions According to EC8

1. Beam Geometric Conditions

- For DCH reinforced concrete beam design, the width of primary seismic beams shall not be lower than 200 mm. And the width to height ratio of the web shall satisfy the expression below [21]:

- transient situations:

$$(\, l_{ot} / b\,) \leq 70 / (h/b)^{1/3} \quad \text{and} \quad h/b \leq 3.5 \tag{4.3}$$

where:

l_{ot} : Distance between torsional restraints.

b : Total depth of beam in central part of l_{ot}.

h : Width of compression flange.

- For DCM and DCH reinforced concrete beam design, the distance between the centroidal axes of the two members should be more than $b_c/4$. Where b_c is the largest cross-sectional dimension of the column normal to the longitudinal axis of the beam.
- To take advantage of the favorable effect of column compression on the bond of horizontal bars passing through the joint, the width b_w of a primary seismic beam shall satisfy the following expression:

$$b_w \leq \min \{b_c + h_w ; 2b_c\} \tag{4.4}$$

where h_w is the depth of the beam and b_c is cross-sectional dimension of column.

2. Column Geometric Conditions

- For DCH reinforced concrete column design, the cross-sectional sides of primary seismic columns, h, shall not be less than 250 mm.
- For DCM and DCH reinforced concrete column design, unless θ, which is Interstorey drift sensitivity coefficient ≤ 1.0, the cross-sectional dimensions of primary seismic columns should not be smaller than one 1/10 of the larger distance between the point of contra flexure and the ends of the column, for bending within a plane parallel to the column dimension considered.

3. Ductile Shear-Wall Geometric Conditions

- For DCM and DCH reinforced concrete ductile shear walls design, the thickness of the web, b_{wo}, (in meters) should satisfy the following expression:

$$b_{wo} \geq \max\{0.15 \text{ or } h_s/20\} \tag{4.5}$$

where h_s is the clear storey height in meters.

- Random openings, not regularly arranged to form coupled walls, should be avoided in primary seismic shear walls, unless their influence is either insignificant or accounted for in analysis, dimensioning and detailing.

4.3.2. Geometric Conditions According to TEC-2007

1. Beam Geometric Conditions

- The geometric requirements of cross-section of beams forming frames together with columns, or of beams connected to structural walls in their own planes are given below:

  a- Width of the beam web shall be at least 250 mm. Web width shall not exceed the sum of the beam height and the width of the supporting column in the perpendicular direction to the beam axis.

  b- Beam height shall not be less than 3 times the thickness of floor slab and 300 mm, nor shall it more than 3.5 times the beam web width.

  c- Beam height should not be more than 1/4 the clear span.

  d- Limitations specified above in relation to beam width and heights are not applicable to reinforced concrete or pre - stressed / prefabricated beams with hinge connections to columns, to coupling beams of coupled structural walls, and to the secondary beams which are connected to frame beams outside the beam-column joints.

- It is essential that design axial force satisfies the condition below:

$$N_d \leq 0.1 \, A_c \, f_{ck} \tag{4.6}$$

Where:

N_d : Axial force calculated under combined effect of seismic loads and vertical loads multiplied with load coefficients.

f_{ck} : Characteristic compressive cylinder strength of concrete.

In order that any structural element be sized and reinforced as a beam. Otherwise such elements shall be sized and reinforced as a column in accordance with columns limitations

2. Column Geometric Conditions

- Shorter dimension of columns with rectangular section shall not be less than 250 mm and section area shall not be less than 75000 mm^2. Diameter of circular columns shall be at least 300 mm.
- In order the gross section area of column (A_c) to be the biggest one of axial pressure strengths calculated under the combined effect of N_{dm} vertical loads and seismic loads, gross section area of column shall satisfy the condition below:

$$A_c \geq N_{dmax} / (0.50\, f_{ck})$$

where:

N_{dmax} : Greater of the axial pressure forces calculated under combined effect of seismic loads and vertical loads.

3. Ductile Shear-Wall Geometric Conditions

- Structural walls are the vertical elements of the structural system where the ratio of length to thickness in plan is equal to at least seven. With the exception of the special cases given:

  1- In buildings where seismic loads are fully carried by structural walls along the full height of building, wall thickness shall not be less than 1 / 20 the highest storey height and 150 mm, provided that both two of the conditions given by equations (4.1) and (4.2), these equations shall be applied at the ground floor level in buildings with stiff peripheral walls in basement stories, whereas it shall be applied at foundation top level for other buildings.

  2- On the walls situated in lateral direction with the elements that the length is equal to at least to 1/5 of the storey length and have storey length bigger than 6 m, wall thickness in the ground may be equal to at least 1 / 20 of horizontal length between the points where it’s situated in lateral direction. However this thickness should not be less than 300 mm.

- With exceptions of the two cases before, the wall thickness shall not be less than 1 / 20 the storey height and 200 mm.

4.4. Reinforcement Conditions

4.4.1. Reinforcement Conditions According to EC8

1- Beam Reinforcement Conditions

Beam reinforcement conditions according to EC8 are explained in table 4.2.

Table 4.2 Generals Rules of EC8 Beams Reinforcement Design [26].

	DCH	DCM
"critical region" length (1)	$1.5h_w$	h_w
- *Longitudinal bars (L):*		
ρ_{min}, tension side (2)	$0.5f_{ctm} / f_{yk}$	
ρ_{max}, critical regions(3)	$\rho' + 0018f_{cd} / (\mu_{\varpi}\, \varepsilon_{sy,\,d}\, f_{yd})$	
$A_{s,min,}$ top & bottom	2Ø14 ($308mm^2$)	-
$A_{s,min}$, critical regions	$0.5A_{s,top}$	-
$A_{s,min,}$ top – spam	$A_{s,top\,-\,supports} / 4$	
$A_{s,\,min,}$ supports bottom	$A_{s,\,bottom\,-\,span} / 4$	-
d_{bL} / h_c – bar crossing interior joint(4)	$\leq \frac{6.25\,(1+0.8\,\nu_d)}{\left(1+0.75\,\frac{\rho'}{\rho_{max}}\right)}\,\frac{f_{ctm}}{f_{yd}}$	$\leq \frac{7.5\,(1+0.8\,\nu_d)}{\left(1+0.5\,\frac{\rho'}{\rho_{max}}\right)}\,\frac{f_{ctm}}{f_{yd}}$
d_{bL} / h_c – bar crossing exterior joint(4)	$\leq 6.25\,(1+0.8\,\nu_d)\,\frac{f_{ctm}}{f_{yd}}$	$\leq 6.25\,(1+0.8\,\nu_d)\,\frac{f_{ctm}}{f_{yd}}$
- *Transverse bars (w):*		
I- Outside critical regions(5)		
Spacing s_w	$\leq 0.75d$	
ρ_w	$0.08\sqrt{(f_{ck}\,(Mpa) / f_{yk}\,(Mpa))}$	
II- In critical regions(5)		
d_{bw} (6)	$\geq 6mm$	
spacing s_w	$\leq \min\{6d_{bL}, h_w/4, 24b_w, 175mm\}$	$\leq \min\{8d_{bL}, h_w/4, 24b_w, 225mm\}$

(1) For beams supporting discontinued (cut-off) vertical elements, the "critical length" shall be $2h_w$, where h_w: is depth of the beam.

(2) f_{ctm} is the main value tensile strength of concrete, and f_{yk} is the characteristic yield strength.

(3) f_{cd} is the design value of concrete compressive strength, μ_ϕ is the value of the curvature ductility factor that corresponds to the basic value, q_o, of the behavior factor used in the

design as: μ_ϖ=2q_o-1 if $T \geq T$C or μ_ϖ=1+2(q_o-1)T_C/T if $T<T_C$. $\varepsilon_{sy,d}$ is the design value of steel at yield, and f_{yd} is the design value of yield strength of steel.

(4) h_c is the column depth in the direction of the bar, d_{bL} is the diameter of the longitude bars and $v_d = N_{Ed} / A_c f_{cd}$ is the column axial load ratio, for the algebraically minimum value of the axial load due to the design seismic action plus concurrent gravity (compression: positive).

(5) The first hoop shall be ≥ 50mm from the first beam end section.

(6) d_{bw} is the diameter of hoops.

2- Column Reinforcement Conditions

Columns reinforcement conditions according to EC8 are explained in table 4.3.

Table 4.3 Generals Rules of EC8 for Columns Reinforcement Design [26].

	DCH	**DCM**
"Critical regions" length is (1)	max{1.5h_c, 1.5b_c, 0.6m,l_c/5}	max{h_c, b_c, 0.45m, l_c/6}
Longitudinal bars (L):		
$\rho_{l\min}$	0.01	
$\rho_{l\max}$	0.04	
Symmetrical cross-sections	$\rho=\rho'$	
At the corners(2)	One bar along each column side	
Spacing between restrained bars	≤ 150mm	≤ 200mm
Distance of unrestrained bar from nearest restrained	≤ 150mm	
Transverse bars (w):		
Outside critical regions:		
Spacing *s*	min{20d_{bL}, h_c, b_c, 400mm}	min{12d_{bL}, 0.6h_c, 0.6b_c, 240mm}
Within critical regions:		
d_{bw} (4)	≥ {6mm, $0.4(f_{ydL}/f_{ywd})^{1/2} d_{bL,max}$}	≥ {6mm, $d_{bLmax}/4$}
Spacing *s*	min{6d_{bL}, b_o/3, 125mm}	min{8d_{bL}, b_o/2, 175mm}
$\omega_{wd,mim}$(5)	0.08	-
$\alpha\omega_{wd}$(6)	$30\ \mu_\phi\ v_d \varepsilon_{sy,d} b_c/b_o - 0.035$	
In critical region at column base:		
$\omega_{wd,mim}$(5)	0.12	0.08
$\alpha\omega_{wd}$	$30\ \mu_\phi\ v_d \varepsilon_{sy,d} b_c/b_o - 0.035$	-

(1) If l_c/h_c <3, the entire length of the column shall be considered as a critical regions and shall be reinforced accordingly. Where l_c is the length of the column, h_c is the largest cross-sectional dimension of the columns (in meters), b_c is the cross-sectional dimension of column.

(2) At least one intermediate bar shall be provided between corner bars along each column side, to ensure the integrity of the beam-column joints.

(3) d_{bw} is the diameter of the hoops.

(4) ω_{wd} the ratio of the volume of confining hoops to that of the confined core to the centerline of the perimeter hoop, times f_{yd}/f_{cd}.

(5) α is the "confinement effectiveness" factor, computed as $\alpha = \alpha_s.\alpha_n$; where $\alpha_s=(1-s/2b_o)$ for hoops and $\alpha_s=(1-s/2b_o)$ for spirals : $\alpha_n=1-\{b_o/((n_h-1)h_o)+h_o/((n_b-1)b)\}/3$ for rectangular hoops with n_b legs parallel to the side of the core with length b_o and n_h legs parallel to the one with length h_o.

(6) Index c denotes the full concrete section and index o the confined core to the central of the perimeter hoop; bois the smaller side of this core.

3- Ductile Shear-Wall Reinforcement Conditions:

Ductile shear-wall reinforcement conditions according to EC8 are explained in table 4.4.

Table 4.4 Generals Rules of EC8 for Ductile Shear-Wall Reinforcement Design [26].

	DCH	**DCM**
"critical regions" length(1)	$\geq$ max (l_w, $H_w/6$) $\leq$ min ($2l_w$, h storey) if $\leq$ 6 storey $\leq$ min ($2l_w$, 2h storey) if > 6 storey	
boundary elements:-		
a) In critical regions		
- length of l_c from the edge $\geq$	$0.15l_w$, $1.5b_w$, length over which $\varepsilon_c > 0.0035$	
- thickness b_w over $\geq$	0.2m; $h_{st}/15$ if $l_c \leq \max(2b_w, l_w/5)$, $h_{st}/10$ if $l_c > \max(2b_w, l_w/5)$	
- vertical reinforcement:		
$\rho_{w,min}$	0.5%	
$\rho_{w,max}$	4%	
confining hoop (w)(2):		
$d_{bw} \geq$	6mm, $0.4(f_{yd}/f_{ywd})^{1/2} d_{bL}$	6mm
spacing $s_w \leq$	$6d_{bL}$, $b_o/3$, 125mm	$8d_{bL}$, $b_o/2$, 175mm
$\omega_{wd} \geq$	0.12	0.8
$\alpha\omega_{wd} \geq$(3)	$30\,\mu\varphi\,(v_d + \omega_v)\,\varepsilon_{sy,d}\,b_c/b_o - 0.035$	
b) over the rest of the wall height	In parts of the section where $\varepsilon_c > 0.2\%$: $\rho_{v,min} = 0.5\%$; elsewhere 0.2% In parts of the sections where $\rho > 2\%$:- - distance of unstrained bar in compression zone from nearest restrained bar $\leq$ 150mm; - hoops with $d_{bw} \geq \max(6\text{mm}, d_{bL}/4)$ & spacing $s_w \leq$ min ($20d_{bL}$, b_{wo}, 400mm) beyond that distance.	
Web:-		
Vertical bars (v) :		
$\rho_{v,min}$	Where in the section $\varepsilon_c > 0.2\%$: 0.5%; elsewhere 0.2%	
$\rho_{v,max}$	4%	
$d_{bv} \geq$	8mm	-
$d_{bv} \leq$	$b_{wo}/8$	
spacing s_v	min($25d_{bw}$, 250mm)	min($3b_{wo}$, 400mm)
horizontal bars (h) :		
$\rho_{h,min}$	0.2 %	max (0.1%, $25\rho_v$)
$d_{bh} \geq$	8mm	-
$d_{bh} \leq$	$b_{wo}/8$	-

spacing $s_h \leq$	min { $25d_{bh}$,250mm }	400mm
axial load ratio v_d $N_{Ed} / A_c f_{cd}$	≤ 0.35	≤ 0.4

(1) l_w is the long side of the rectangular wall section or rectangular part thereof; H_w is the total height of the wall; h_{storey} is the storey height.

(2) For DCM: If, under the maximum axial force in the wall from the analysis for the design seismic action plus concurrent gravity the wall axial load ratio $v_d = N_{Ed}/A_c f_{cd}$ satisfies $v_d \leq 0.15$, the DCL rules may be applied for the confining reinforcement of boundary elements; these DCL rules apply also if this value of the wall axial load ratio is $v_d \leq 0.2$ but the value of q used in the design of the building is not greater than 85% of the *q*-value allowed when the DCM confining reinforcement is used in boundary elements.

(3) $\mu\varphi$ is the value of the curvature ductility factor that corresponds as: $\mu\varphi=2q\text{o}-1$ if $T \geq T\text{C}$ or $\mu\varphi=1+2(q\text{o}-1)T\text{C}/T$ if $T<T\text{C}$, to the product of the basic value q_o of the behavior factor times the value of the ratio M_{Edo} / M_{Rdo} at the base of the wall $\varepsilon_{sy,d} = f_{yd}/E_s$,$\omega_{vd}$ is the mechanical ratio of the vertical web reinforcement.

4.4.2. Reinforcement Conditions According to TEC-2007

1- Beam Reinforcement Conditions:

Beam reinforcement conditions according to TEC-2007 are explained in table 4.5.

Table 4.5 Generals Rules of TEC-2007 Beams Reinforcement Design.

	HDL	NDL
Longitudinal reinforcement:		
ρ_{min} (1)	$\geq 0.8\ f_{ctd} / f_{yd}$	
ρ_{max}	≤ 0.02	
D_{bar} (2)	$\geq$ 12mm	
- For first & second seismic zone (1) $A_{s,bottom-support}$	$\geq 0.5\ A_{s,top-supports}$	
- For third & forth seismic zone (1) $A_{s,bottom-support}$	$\geq 0.3\ A_{s,top-supports}$	
s_b	$\leq$ 300mm	
$A_{s,extended}$	$0.25\ A_{s,top-beam}$	
Beam-column		
$A_{s,extended}$		
For 90˚ reinforce bent inside of column		
- horizontal	≥ 0.41 b	
- vertical	≤ 12 Ø	
Spacing s_{hoops}	$\leq 0.25\ b_d$ (4), 100mm	
Transfer reinforcements:		
Mechanical connections, welded lap splice	$\geq$ 600mm	
"Confinement zone" length	$2b_d$	
s of first hoop from column	50mm	
s_{hoop}	$0.25\ b_d$, $8D_{bar,min}$, 150mm	

(1) The minimum ratio of top tension reinforcements at beams support.

(2) D_{bar} is the diameter of longitudinal rebars.

2- Column Reinforcement Conditions:

Column reinforcement conditions according to TEC-2007 are explained in table 4.6.

Table 4.6 Generals Rules of TEC-2007 Columns Reinforcement Design.

	HDL	**NDL**
Longitudinal reinforcements :		
ρ_{min}	≥ 0.01	
ρ_{max}	≤ 0.04	
min number of rebars	- Rectangular sections: 4Ø16 or 6Ø14 - Circular sections: 6Ø14	
-lap splices sec ρ_{max}.	0.06	
bottom end – column(1) $\leq 50\%$ $> 50\%$	$\geq 1.25\ l_b$ $\geq 1.5\ l_b$	
Transfer reinforcements :		
"confined zone" length(2)	$\geq \min\{D_{min}, 1/6\ h_c, 500mm\}$	
reinforcement diameter	$\geq$ Ø 8	
extended (3)	$\geq 2D_{min}$	
continued (4)	$\geq \{25D_{max}, 300\}$	
spacing s_{hoop}	$\leq [1/3D_{min}, 100mm]$ $\geq 50mm$	
a(5)	$\leq D_{hoop}$	
pitch of spirals	$\leq [\ 1/5\ D_{core}, 80mm]$	
-If $N_d > 0.2\ A_c\ f_{ck}$ (6) :		
columns with hoops	$A_{sh} \geq 0.3\ s\ b_k\ [(A_c / A_{ck})-1]\ (f_{ck} / f_{ywk})$ $A_{sh} \geq 0.075\ s\ b_k\ (f_{ck} / f_{ywk})$	
columns with spirls	$\rho_s \geq 0.45\ [(A_c/A_{ck})-1]\ (f_{ck} / f_{ywk})$ $\rho_s \geq 0.12\ (f_{ck} / f_{ywk})$	
- if $N_d \leq 0.2\ A_c\ f_{ck}$		
columns with hoops	$A_{sh} \geq 2/3\ 0.3\ s\ b_k\ [(A_c / A_{ck})-1]\ (f_{ck} / f_{ywk})$ $A_{sh} \geq 2/3\ 0.075\ s\ b_k\ (f_{ck} / f_{ywk})$	
columns with spirals	$\rho_s \geq 2/3\ 0.45\ [(A_c/A_{ck})-1]\ (f_{ck} / f_{ywk})$ $\rho_s \geq 2/3\ 0.12\ (f_{ck} / f_{ywk})$	
"Central columns"(6) reinforcement:		
- Transfer reinforcement	$\leq$ Ø8	
s_{hoops}, crossties	$\leq 1/2\ D_{max}$	
a(5)	$25\ D_{hoop}$	

(1) In case where lap splice of column longitudinal reinforcement are mad at the bottom end.

(2) D_{min} is the smallest dimension of beam cross-section, h_c is clear hagith of the column.

(3) Reinforcement shall be exceeding into foundation.

(4) The reinforcement shall be continued the length inside the foundations.

(5) a, is the lateral distance between legs of hoops and crossties.

(6) N_d is the axial force calculated under combine effect of seismic loads and vertical loads multiplied with loads coefficients, A_c is the gross area of column or wall zone, f_{ck} is the characteristic compressive cylinder strength of concrete, A_{ck} concrete core area within outer edges of confinement reinforcement, f_{ywk} is the characteristic yield strength of transverse reinforcement.

3- Ductile Shear-Wall Reinforcement Conditions

Ductile shear wall reinforcement conditions according to TCE-2007 are explained in table 4.7.

Table 4.7 Generals Rules of TEC-2007 Ductile Shear-Wall Reinforcement Design.

	HDL	**NDL**
"critical wall height"(1)	$\geq l$w, $\geq H_w$, $\leq 2l$	
Web reinforcement:		
ρ_{min}(2)	≥ 0.0025	
spacing s	≤ 250mm	
Or :-		
ρ_{min}(3)	0.0015	
spacing (s) (3)	≤ 300mm	
ρ_{min}(4)	0.002	
Wall end zones reinforcement:		
ρ_{min} (5)	≥ 0.001	
As_{min}	≥ 4 Ø 14	
Transfer reinforcement:		
D_{min}	$\geq$ 8mm	
a(5)	$\leq 25D_{hoop}$	
spacing (s) (7)	$\leq 0.5b_{web}$ or 100mm ≥ 50mm	
confinement zones(8)	$\geq 2/3\ A_{sh}$	
extended steel(9)	$\geq 2b_{web}$	

(1) If $H_w/l_w \leq 2.0$ web section shall be considered as the full section of the wall, where H_w is the wall height measured from level that reduce more than 20% of the length of the wall in plan or from the top of the ground.

(2) Total cross section area of each the vertical and the horizontal web reinforcement on both faces of structural wall.

(3) If equations 4.1 and 4.2 are satisfied.

(4) For critical wall height zones.

(5) The ratio will be increase to 0.002 along the "critical wall height" an defined before.

(6) The lateral distance between legs of hoops and cross sties.

(7) Vertical spacing of the hoops and / or crossties.

(8) For confinement zones of columns $\geq 2/3\ A_{sh}$ shall be provided along the "critical wall height".

(9) Such reinforcement shall be extended into the foundations.

Chapter V

5. NUMERICAL APPLICATIONS

5.1. Overview

In this chapter, structures form the current architectural project, 5 different situations ranging from 3 to 7 storey reinforced concrete building structures were examined in the light of TEC-2007 and EC8 design rules by using STA4-CAD V12.1, commercial structural analysis and design program.

5.2. Introduction

In general, rough constructions work, in multi-storey reinforced concrete building are corresponds to the approximately 40% of the total cost of reinforced concrete building structure construction cost. This rough construction works consists of; reinforcement work, concrete work and formwork. See figure 5.1.

Figure 5.1 Rough Construction of Multi-Storey Reinforced Concrete Building Structure.

In this study, the investigated buildings are multi-storey structures. General building information's of these buildings are shown in table 5.1.

Table 5.1 General Buildings Information

Type of structure	Reinforced concrete
Storey height	3.06m
Total floor area	238m^2
Intended purpose	Residential
Concrete class	C25
Steel class	S420

The plan dimensions of the investigated reinforced concrete building structure's, typical at all floors are, 15.4m in the direction of X, and 16.8m in the direction of Y, which is symmetric in one direction. See figure 5.2.

The structural systems of the investigated reinforced concrete building's structures are selected as structural systems consisting of structural shear-wall and moment resisting frames in both directions. It is assumed that the structural system of the buildings have a high ductility level.

The general rules of earthquake resistant structural system mentioned in chapter 3 and special design rules for reinforced concrete buildings mentioned in chapter 4, according to EC8 and TEC-2007 are considered in the investigated reinforced concrete buildings structure design.

During the analysis, foundations have been neglected. Therefore, only the superstructure been have analyzed. Load combinations were taken according to TEC-2007 and EC8.

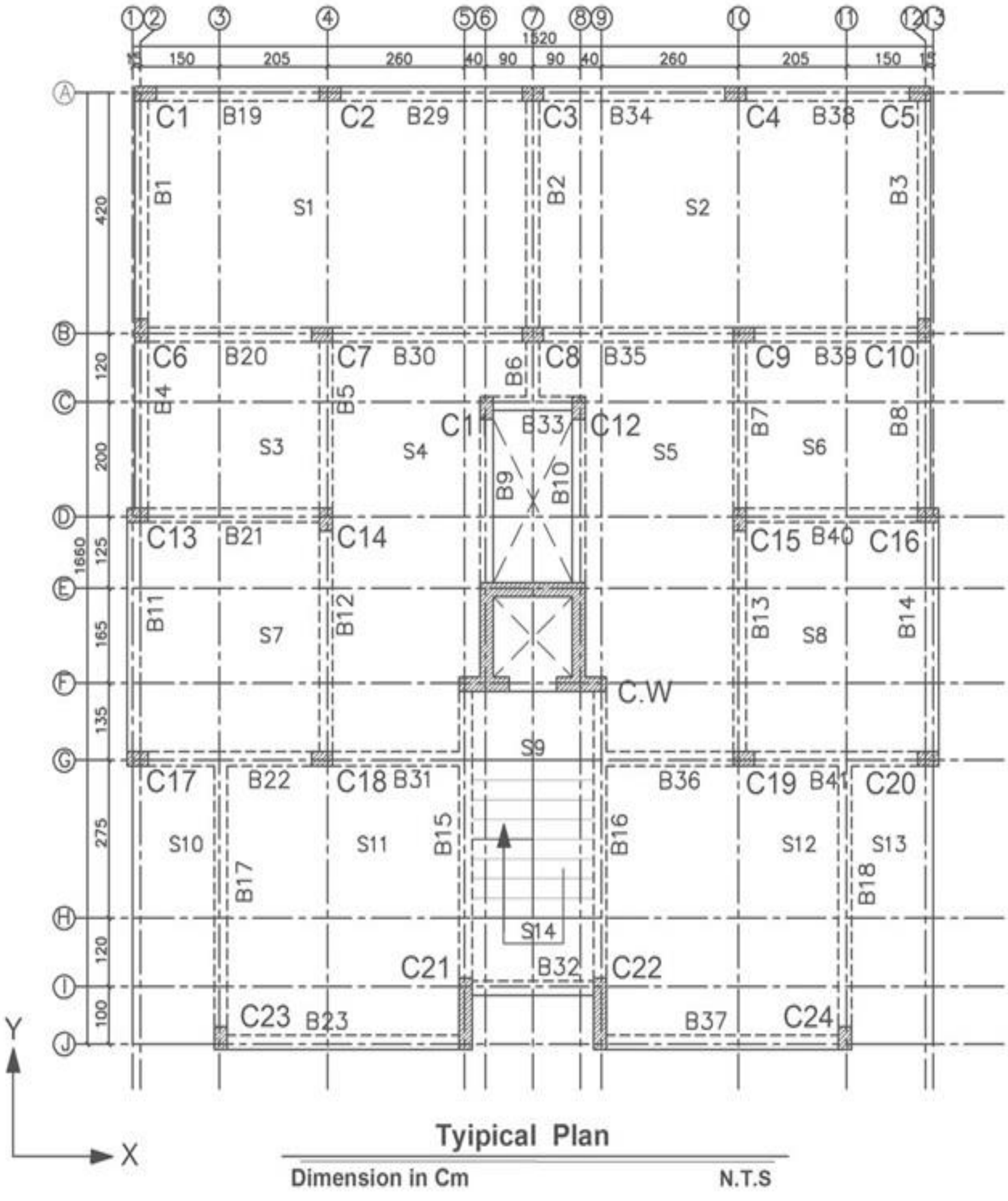


Figure 5.2 Typical Plan of the Investigated Reinforced Concrete Building

The analyzing and designing of multi storey reinforced concrete buildings is made by using STA4-CAD V12.1 commercial computer program. STA4-CAD is an integrated package program of software capable of executing three dimensional analyses and creating drawing of multi-storey reinforced concrete building. See figure 5.3.

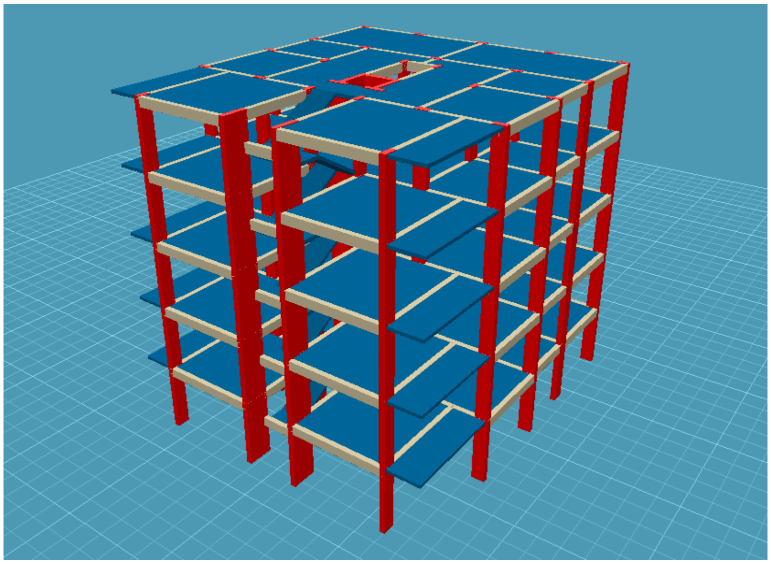


Figure 5.3 3D View of Structure by Using STA4-CAD V12.1

Upon the results of the analysis, quantity surveys of rough work constructions have been calculated with Turkish Republic of Northern Cyprus (TRNC), Planning and Organization's office, 2012 unit prices, which is in Turkish-Lira (TL), as shown in Table 5.2. The bills of quantities presented are not including taxes or transportation fees.

Table 5.2 Rough Work Unit Price [25].

Description	**Unit Price (TL)**
Reinforcements (ton)	2260
Concrete (m^3)	148
Formwork (m^2)	20

It is assumed that the investigated reinforced concrete building structures are established in Cyprus – Nicosia, where the ground conditions and seismic zone coefficient according to the national annex of this area are considered in the design.

For the investigated reinforced concrete building structures, general and specific building data's are shown in 5.4. Bill of quantities and total cost for rough constructions are shown in 5.5. Moreover, dimensions, loading conditions and reinforcements of columns, beam, slabs and shear-wall are shown in appendices.

5.3. Loading

In this study, during the dimensioning of reinforced concrete building structures, permanent loads are consists of beams, columns,… etc., moveable and lateral loads were designed according to their critical values.

The program calculate the own weights of structural elements such as beams and columns due to their unit weights.

Moreover weights of the walls and covering elements that depend on the choice of materials are included in the calculations. Live loads were taken according to TS-498.

For both regulations, the load combinations are given in table below.

Table 5.3 Load Combinations

TEC-2007	EC8
0.90 G ± 1.00 C_E	1.35 G + 1.35 C_E
1.00 G + 1.00 Q + 1.00 Cs ± 1.00 E	1.00 G + 1.00 Q + 1.00 C_s ± 1.00 C_E
1.40 G + 1.60 Q	1.35 G + 1.50 Q
1.40 G + 1.60 Q + 1.60 C_s	1.35 Q + 1.35 Cs ± 1.35 C_E
1.40 G	1.00 C_s ± 1.20 C_E
1.00 G + 1.00 Q ± 1.00 C_E	1.20 C_s ± 1.35 C_E
1.00 G + 1.30 Q ± 1.30 C_w	±1.00 C_w
1.00 G + 130 Q + 1.00 C_s ± 130 C_w	1.00 G + 1.00 Cs
0.90 G ± 1.30 C_w	1.00 Q ± 1.00 C_w
0.90 G + 0.90 Cs ± 1.30 C_w	1.35 Cs ± 1.35 C_E
	1.35 Q ± 1.35C_w ± 1.35 C_E
	1.35 G + 1.35 C_E ± 1.00 C_w
	1.00 G + 1.35 Q + 1.00 ± 1.35 C_w

5.4. Reinforced Concrete Buildings Data

The reinforced concrete building data are used as a program input data to design multi-storey reinforced buildings according to EC8 and TEC-2007 rules and limitations. In general there are two types of data used for the building's design which are general building datas and specific building datas.

5.4.1. General Buildings Datas

The general building datas are common between EC8 and TEC-2007 for the investigated buildings, as shown in table 5.4.

Table 5.4 General Building Data

Horizontal force factor (R,q)	7
Importance factor (I)	1
Live load participation factor (n)	0.3
Allowable bearing pressure*	20 t/m^2
Modulus of subgrade reaction (K_o)*	2000 t/m^3
Concrete density	2.5 t/m^3
Earthquake analysis method	Mode superpotion method
Seismic analysis min force load ratio (β)	0.9
Seismic loading eccentricity	0.12

* According to soil investigation report for Nicosia which have been done by Geology and Mines department of TRNC [10].

5.4.2. Specific Building Data

Two regulations been used in Cyprus, Eurocode regulation that is being used in the southern part, and the Turkish regulations that is in effect in the northern part. The specific building data are changing according to designing codes limitations, rules and national annexes of that area.

The seismic zonation for Turkey is based on ground acceleration values with %10 probability of exceedance in 50 years. i.e. 475 years mean return period. Five seismic zone (I, II, III, IV, V), are defined.

The seismic building code of Cyprus includes seismic zonation based on ground acceleration values with %10 probability of exceedance in 50 years. i.e. 475 years mean return period. In a recent revision of the code, three seismic zones (1, 2, 3) are defined.

5.4.2.1. Specific data for reinforced concrete building design according to EC8

The specific data's for reinforced concrete building design according to EC8 which is used to design and analyses the buildings are shown in table 5.5.

Table 5.5 Specific Building Data According to EC8

Seismic zone coefficient (a_{gR}) (1)	0.2
Spectrum characteristic period (T_b/T_c) (2)	0.2/0.6
Design method	Eurocode ultimate design method

(1) According to EC8 national annex of Cyprus for Nicosia region [17]

(2) According to soil investigation report for Nicosia which have been done by Geology and Mines department of TRNC [10].

5.4.2.2. Specific data for reinforced concrete building design according to TEC-2007

Turkey and TRNC are using TEC-2007 recently. In this study, case I and case II are mentioned below;

- **Case I:** data collected from the southern part of Cyprus which considered as an official data, as shown in table 5.6.

- **Case II:** data collected from the northern part of the island which is considered as a formal data used by civil engineers in TRNC, as shown in table 5.6.

Table 5.6 Specific Building Data According to TEC-2007

	Case I	**Case II**
Seismic zone coefficient (A_o)	0.2 (1)	0.3 (2)
Spectrum characteristic period (T_a/T_b)(3)	0.15/0.4	
Design method	TS-500 ultimate design method	

(1) According to EC8 National Annex of Cyprus for Nicosia region [17].

(2) According to TRNC [10].

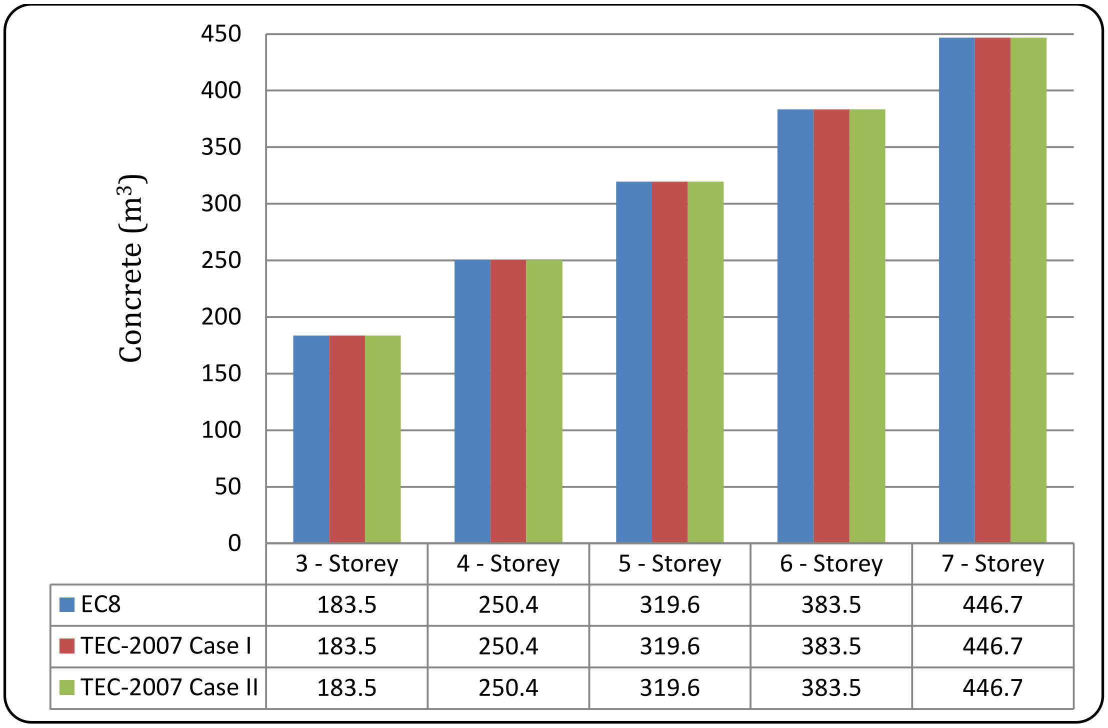
(3) According to soil investigation report for Nicosia which have been done by Geology and Mines department of TRNC [10].

5.5. Results of Analysis

After the analysis and design of multi storey reinforced concrete buildings using STA4-CAD V12.1 computer program, according to EC8 and TEC-2007, rules and limitations, the total cost for superstructure's of multi-storey building have been calculated and presented in table 5.7, and the rough construction works that consist of concrete, formwork and reinforcements amount for EC8 and TEC-2007 (Case I & II) are shown in figure 5.4 – 5.7, and finally Rough work cost per unit floor area is given in figure 5.8

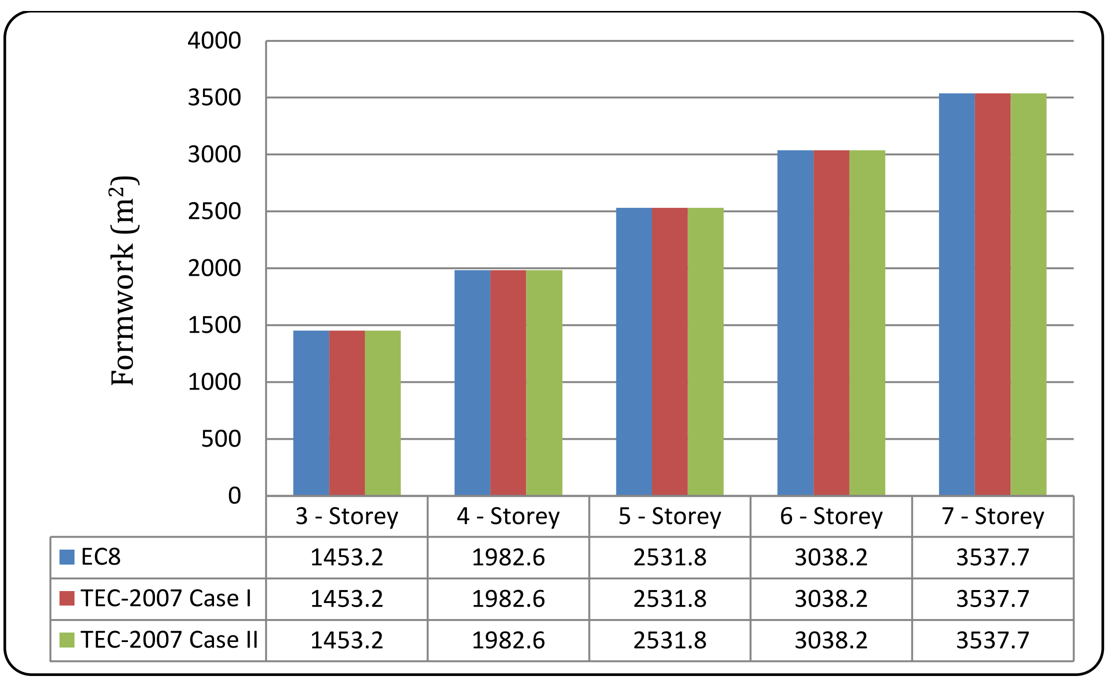
Table 5.7 Results of Reinforced Concrete Building Analysis

Number of Storey	Total Height (m)	Building Code	Total Weight (Ton)	Concrete (m^3)	Formwork (m^2)	Reinforcement (Ton)	Total Rough Construction Cost (TL)
3	9.18	EC8	845.0	183.5	1453.2	18.2	97354
		TEC-2007 Case I	847.6	183.5	1453.2	18.0	96902
		TEC-2007 Case II	847.7	183.5	1453.2	18.1	97128
4	12.24	EC8	1168.9	250.4	1982.6	25.6	134552
		TEC-2007 Case I	1168.7	250.4	1982.6	25.4	134100
		TEC-2007 Case II	1169.0	250.4	1982.6	25.7	134778
5	15.30	EC8	1506.8	319.6	2531.8	32.5	171387
		TEC-2007 Case I	1507.0	319.6	2531.8	32.4	171161
		TEC-2007 Case II	1508.3	319.6	2531.8	33.6	173873
6	18.36	EC8	1825.2	383.5	3038.2	39.4	206566
		TEC-2007 Case I	1826.2	383.5	3038.2	39.2	206114
		TEC-2007 Case II	1826.6	383.5	3038.2	40.8	209730
7	21.42	EC8	2136.9	446.7	3537.7	46.3	241504
		TEC-2007 Case I	2137.4	446.7	3537.7	46.0	240826
		TEC-2007 Case II	2138.3	446.7	3537.7	47.9	245120



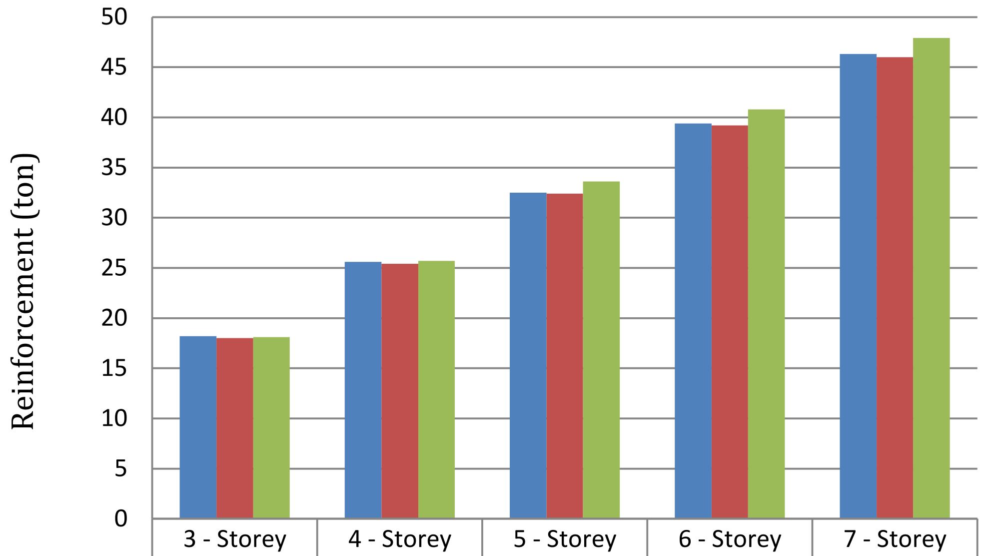
	3 - Storey	4 - Storey	5 - Storey	6 - Storey	7 - Storey
EC8	183.5	250.4	319.6	383.5	446.7
TEC-2007 Case I	183.5	250.4	319.6	383.5	446.7
TEC-2007 Case II	183.5	250.4	319.6	383.5	446.7

Figure 5.4 Concrete Amounts for Multi-Storey Buildings for EC8 and TEC-2007 (Case I & II).



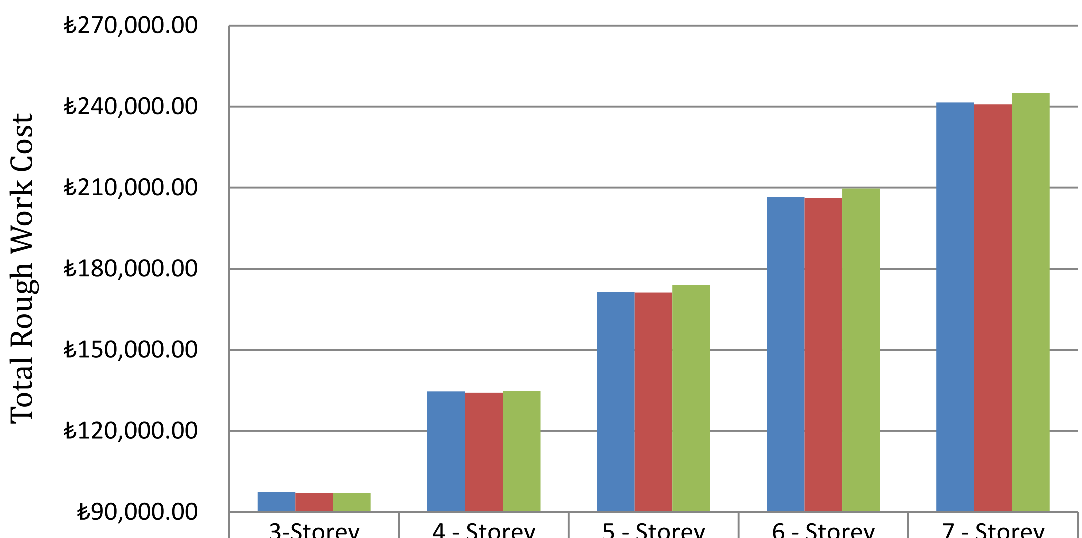
	3 - Storey	4 - Storey	5 - Storey	6 - Storey	7 - Storey
EC8	1453.2	1982.6	2531.8	3038.2	3537.7
TEC-2007 Case I	1453.2	1982.6	2531.8	3038.2	3537.7
TEC-2007 Case II	1453.2	1982.6	2531.8	3038.2	3537.7

Figure 5.5 Formwork Amounts for Multi-Storey Buildings for EC8 and TEC-2007 (Case I & II).



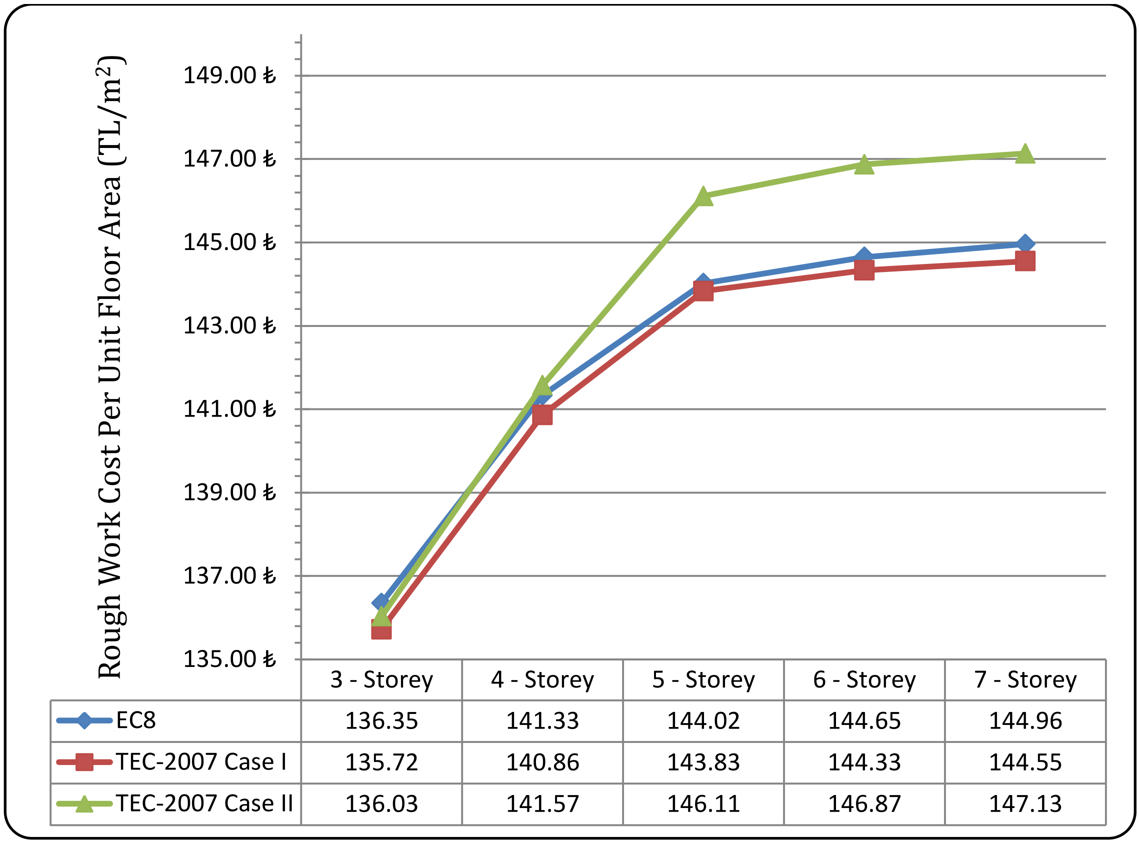
	3 - Storey	4 - Storey	5 - Storey	6 - Storey	7 - Storey
EC8	18.2	25.6	32.5	39.4	46.3
TEC-2007 Case I	18	25.4	32.4	39.2	46
TEC-2007 Case II	18.1	25.7	33.6	40.8	47.9

Figure 5.6 Reinforcement Amounts for Multi-Storey Buildings for EC8 and TEC2007 (Case I & II).



	3-Storey	4 - Storey	5 - Storey	6 - Storey	7 - Storey
EC8	97354	134552	171387	206566	241504
TEC-2007 Case I	96902	134100	171161	206114	240826
TEC-2007 Case II	97128	134778	173873	209730	245120

Figure 5.7 Total Rough Work Costs for Multi-Storey Buildings for EC8 and TEC2007 (Case I & II).



	3 - Storey	4 - Storey	5 - Storey	6 - Storey	7 - Storey
EC8	136.35	141.33	144.02	144.65	144.96
TEC-2007 Case I	135.72	140.86	143.83	144.33	144.55
TEC-2007 Case II	136.03	141.57	146.11	146.87	147.13

Figure 5.8 Reinforced Concrete Building Rough Work Cost Per Unit Floor Area for Multi Storey Buildings.

Chapter VI

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

Cyprus lies in one of the active seismic regions of the Eastern Mediterranean basin. The island was struck by numerous earthquakes in its history.

Building codes are sets of regulations governing the design, constructions, alteration, and maintenance of structures. They specify the minimum requirements to adequately safeguard the health, safety, and welfare of building occupants. They are legal documents which represent the minimum requirements for obtaining safe structures.

In this study EC8 and TEC-2007 seismic design codes are examined and compared with each other in terms of design conditions and cost.

The following conclusion can be drawn as a result of this comparative study:

The elastic response spectrum for acceleration, which is used for computing elastic earthquake force, shows diversity, from one earthquake to another and it is affected by local ground conditions. Theoretically, seismic ground motions are shown by elastic acceleration spectrum in both building codes. Spectrum characteristic periods are defined due to the local site classes. The irregularities of analysis were examined in both regulations. For method of analysis, both similar static and dynamic procedures were used in EC8 and TEC-2007. During comparison, it has observed that there are only minor difference regarding calculation steps and limitations.

In TRNC, civil engineers in practical life are using STA4-CAD commercial package of software widely. The program includes some options related to several regulations such as TEC-2007, EC8, UBC, etc.

According to the earthquake table given by the Chambers of Civil Engineers of TRNC to its members, the northern part of Nicosia is assumed to be in second earthquake region in which seismic zone coefficient, A_0, is taken as 0.3, this condition is expressed as TEC-2007 (Case II) in Chapter V.

As a result of the comparison of EC8 and TEC-2007 (Case II) as the number of storey increases, the difference of rough construction cost increases at the same time. The logical reason is that, the TEC-2007 leads us to be more precautious with its own coefficient which is explained in 5.4.2.2. Because, currently, there is no detailed and official seismic zone map announced by the governments office. This can be helpful or safety, however, this results in high rough construction cost.

According to European standards, looking from National annex of Cyprus, the seismic zonation map for Cyprus, Nicosia region, is assumed to be in the third earthquake region, in which, seismic zone coefficient, A_0, is taken as 0.2. This condition is expressed as TEC-2007 (Case I) in Chapter V.

From this point of view, EC8 and TEC-2007 (Case I) show parallelism in terms of building cost.

The design outputs of the program shows that the cross-sections for the structural elements are all same. The difference can be seen in the reinforcement amount.

6.2. Recommendation

In the light of this study, TRNC has to specify its own official coefficients, suitable for its own conditions or the use of Eurocodes would be appropriate during the entry process of Turkey's and TRNC's to European Union. Regarding the civil engineering perspective, it would be efficient to follow the improvements in the world.

6.3. Suggestion for Further Research

Recent earthquakes have increased the number of seismic assessment projects as well. In this limited study, the case study building system explained in Chapter V can be developed by evaluating the performance of an existing structure. The existing reinforced concrete structural system can assessed comparatively by employing linear and non-linear assessment procedures according to two different seismic codes that is used in this study.

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APPENDIX I

The percentages that can be used during the cost estimations.

BİNALARLA İLGİLİ TESBİTLER YAPILIRKEN YARARLANILABİCEK YÜZDELER

I. (BODRUMSUZ) ZEMİN VE BİRİNCİ KATLI BİNALAR

	Yüzde (%)
a) Temel	7
b) Zemin kat	15
c) Birinci kat	17
d) Çatı	9
e) Doğrama	12
f) İç sıva	4
g) Dış sıva	3
h) Boya, badana	3
i) Kaplamalar	7
j) Elektrik tesisatı	5
k) Sıhhi tesisat	7
l) Kalorifer tesisatı	8
m) Müteferrik işler	3

II. BODRUMLU ZEMİN VE BİRİNCİ KATLI BİNALAR

	Yüzde(%)
a) Temel	7
b) Bodrum kat	8
c) Zemin kat	13
d) Birinci kat	14
e) Çatı	8
f) Doğrama	10
g) İç sıva	4
h) Dış sıva	3
i) Boya badana	3
j) Elektrik tesisatı	5
k) Kaplamalar	7
l) Sıhhi tesisat	7
m) Kalorifer tesisatı	8
n) Müteferrik işler	3

III. BODRUMSUZ ZEMİN VE BİRİNCİ VE İKİNCİ KATLI BİNALAR

	Yüzde (%)
a) Temel	5
b) Zemin kat	10
c)Birinci kat	12
d) İkinci kat	12
e) Çatı	7
f) Doğrama	12
g) İç sıva	4
h) Dış sıva	3
i) Boya badana	3
j) Kaplamalar	8
k) Elektrik tesisatı	5
l) Sıhhi tesisat	7
m) Kalorifer tesisatı	8
n) Müteferrik işler	4

IV. BODRUMLU ZEMİN BİRİNCİ VE İKİNCİ KATLI BİNALAR

	Yüzde (%)
a) Temel	5
b) Bodrum kat	8
c) Zemin kat	9
d) Birinci kat	11
e) İkinci kat	11
f) Çatı	6
g) Doğrama	10
h) İç sıva	4
i) Dış sıva	3
j) Boya badana	3
k) Kaplamalar	6
l) Elektrik tesisatı	5
m) Sıhhi tesisat	7
n) Kalorifer tesisatı	8
o) Müteferrik işler	4

V. 4-5 KATLI BİNALAR

	Yüzde (%)
a) Kaba inşaat	40
b) Çatı	4
c) Doğrama	10
d) İç sıva	5
e) Dış sıva	2
f) Boya badana	3
g) Kaplamalar	9
h) Elektrik tesisatı	5
i) Sıhhi tesisat	7
j) Kalorifer tesisatı	8
k) Müteferrik işler	7

VI. 8.KATTAN DAHA FAZLA BİNALAR

	Yüzde (%)
a) Kaba inşaat	45
b) Çatı	3
c) Doğrama	10
d) İç sıva	5
e) Dış sıva	2
f) Boya badana	3
g) Kaplamalar	7
h) Elektrik tesisatı	5
i) Sıhhi tesisat	7
j) Kalorifer tesisatı	8
k) Müteferrik işler	5

NOT:

1) " Temel" e temal kazısı, dolgu ve imalatı blokaj grobeton ve su basmanını duvarlara dahildir.
2) "Bodrum kat" a bodrum kat betoname ve duvar işleri dahildir.
3) "Zemin kat" a zemin kat betoname ve duvar işleri dahildir .
4) "Birinci kat" a birinci kat betoname ve duvar işleri dahildir.
5) "İkinci kat" a ikinci kat betoname ve duvar işleri dahildir.
6) "Kaba inşaat" a temel kazı,dolgu ve imalatı blokaj grobeton ve su basmanını duvarları ile katların betoname ve duvar işleri dahildir.
7) "Çatı "ya çatman ahşap, çinko ve kiremit işleri yağmur inişleri harpusta duvarları teres tecridi ve kaplaması dahildir.
8) "Doğrama" ya ahşap kapı pencereleri cam ve madeni aksam dahildir.
9) "Kaplamalar" a döşeme ve duvar kaplamaları ,tayans ,tecrit, dolgu ve curut betonları dahildir.
10) "Müteferrik işlere" demir imalat (kapı, merdiven ve balkon korkulukları) denizlik ve parepetler , tezgah altı ve üstü dolapları, gömme dolap, davlumbaz, bacalar ,baca küllük, temizleme kapakları ve temizlik dahildir.

SSK Genel Müdürlüğü "Konut İnşaat Sözleşmelerinden" yararlanılmıştır.

APPENDIX II

Rough construction unit prices, according to Planning Office, 2012, TRNC.

K.K.T.C.
BAYINDIRLIK VE ULAŞTIRMA BAKANLIĞI
PLANLAMA VE İNŞAAT DAİRESİ

TARİH 1 TEMMUZ 2012 - 31 ARALIK 2012 ARASI GEÇERLİDİR.

(K.D.V. Hariç)

(MÜTEAHHİT KARI DAHİL)

İÇERİK

A

6.	**BETONLAR:**		
6.1	C14	m^3	122,00
6.2	C16	m^3	126,00
6.3	C18	m^3	130,00
6.4	C20	m^3	145,00
6.5	C25	m^3	148,00
6.6	C30	m^3	158,00
6.7	Köpük beton 500 dozajlı	m^3	180,00
6.8	Köpük beton 700 dozajlı	m^3	216,00
7.	**BETONARME BETONU İŞLERİ:** (kalıp + demir + beton)		
7.1	C14 (bahçe duvarı vb.)	m^3	390,00
7.2	C16 (bahçe duvarı vb.)	m^3	425,00
7.3	C18 (bahçe duvarı vb)	m^3	438,00
7.4	C20	m^3	480,00
7.5	C25	m^3	500,00
7.6	C30	m^3	520,00
7.7	C14 Blokaj üzeri ızgaralı betonarme betonu,subasman vl	m^3	340,00
7.8	C16 Blokaj üzeri ızgaralı betonarme betonu,subasman vl	m^3	350,00
8.	**BETONARME DEMİRLERİNİN İŞLENMESİ:** (Malzeme Dahil)		
8.1	0 10 - 0 24mm.lik betonarme demirlerin projesine göre bükülmesi ve yerine konması.	Ton	2.260,00
9.	**KALIP İŞLERİ:**		
9.1	**Düz Yüzeyli Beton ve Betonarme Kalıbı:**		
	a- Zemin kat ve üzeri beton ve betonarme kalıbı.	m^2	20,00
	b- Merdiven basamağı kalıbı.	mt	32,00
9.2	**Çıplak Yüzeyli Beton ve Betonarme Kalıbı:**		
	a- Zemin kat ve üzeri beton ve betonarme kalıbı.	m^2	28,00

A

APPENDIX III

Typical building plan and information on structural members.

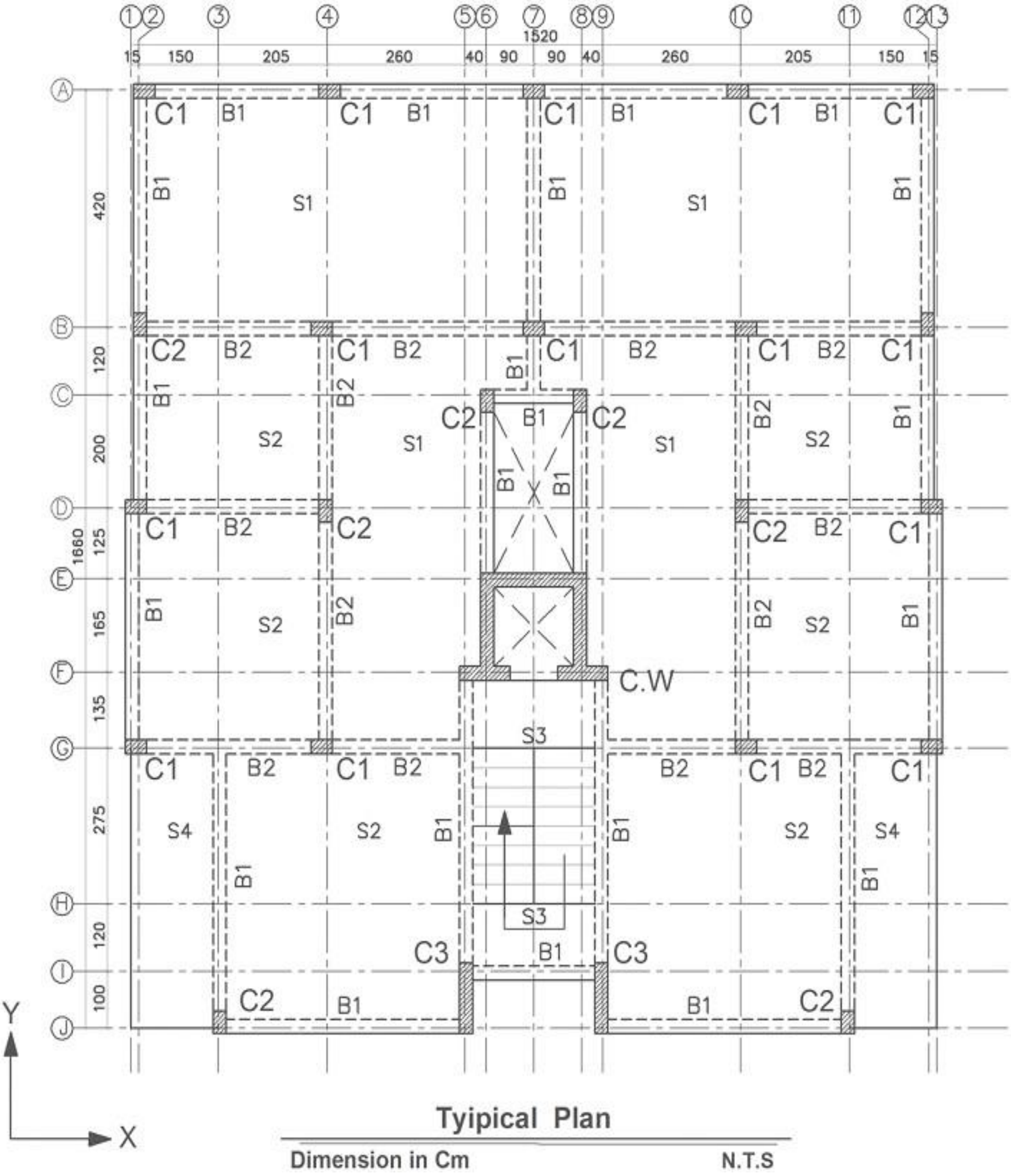


Figure 1. Typical Building Plan

1- Columns

Table A1. Layout of columns for multi-storey reinforced concrete building.

Number of Storey at the Building	**Column Type**	**b_x**	**b_y**	**Shape**
3 Storey Building	C1	40	25	Rectangular
	C2	25	40	Rectangular
	C3	25	125	Rectangular
4 Storey Building	C1	50	25	Rectangular
	C2	25	50	Rectangular
	C3	25	125	Rectangular
5, 6 & 7 Storey Building	C1	60	25	Rectangular
	C2	25	60	Rectangular
	C3	25	125	Rectangular

2- Beams

Table A2. Layout of beams for multi-storey reinforced concrete building

Number of Storey at the building	**Beam Type**	**Dimensions**	**Type of carrying wall**
3, 4, 5, 6 & 7 Storey Building	B1	25 X 50	Internals wall
	B2	25 X 50	External wall

3- Slabs

Table A3. Layout of slab for multi-storey reinforced concrete building**.**

Number of Storey at the Building	Slab Type	Thickness	Description of Slab
3, 4, 5, 6 & 7 Storey Building	S1	15	Slab carrying internal walls
	S2	15	Slab without carrying internal walls
	S3	17	Slab for satires
	S4	15	Slab for balcony

4- Shear-Wall

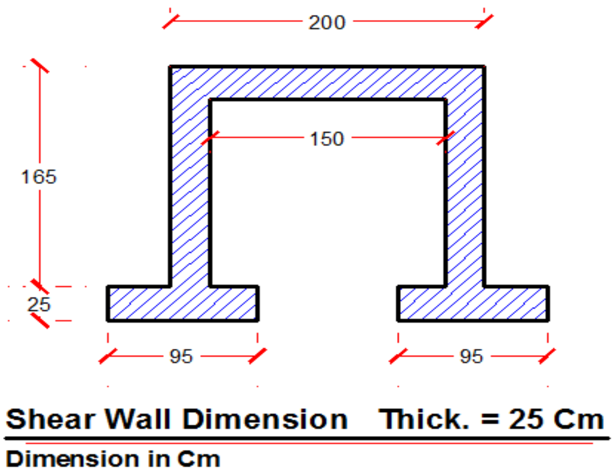


Figure 2. Layout of Shear-Wall for Multi-storey Reinforced Concrete Building

APPENDIX IV

Ministry of Labour and Social Security building, soil investigation report.

KKTC

Çevre ve Doğal Kaynaklar Bakanlığı

Jeoloji ve Maden Dairesi

"ÇALIŞMA VE SOSYAL GÜVENLİK BAKANLIĞI BİNASI" ZEMİN ETÜD RAPORU

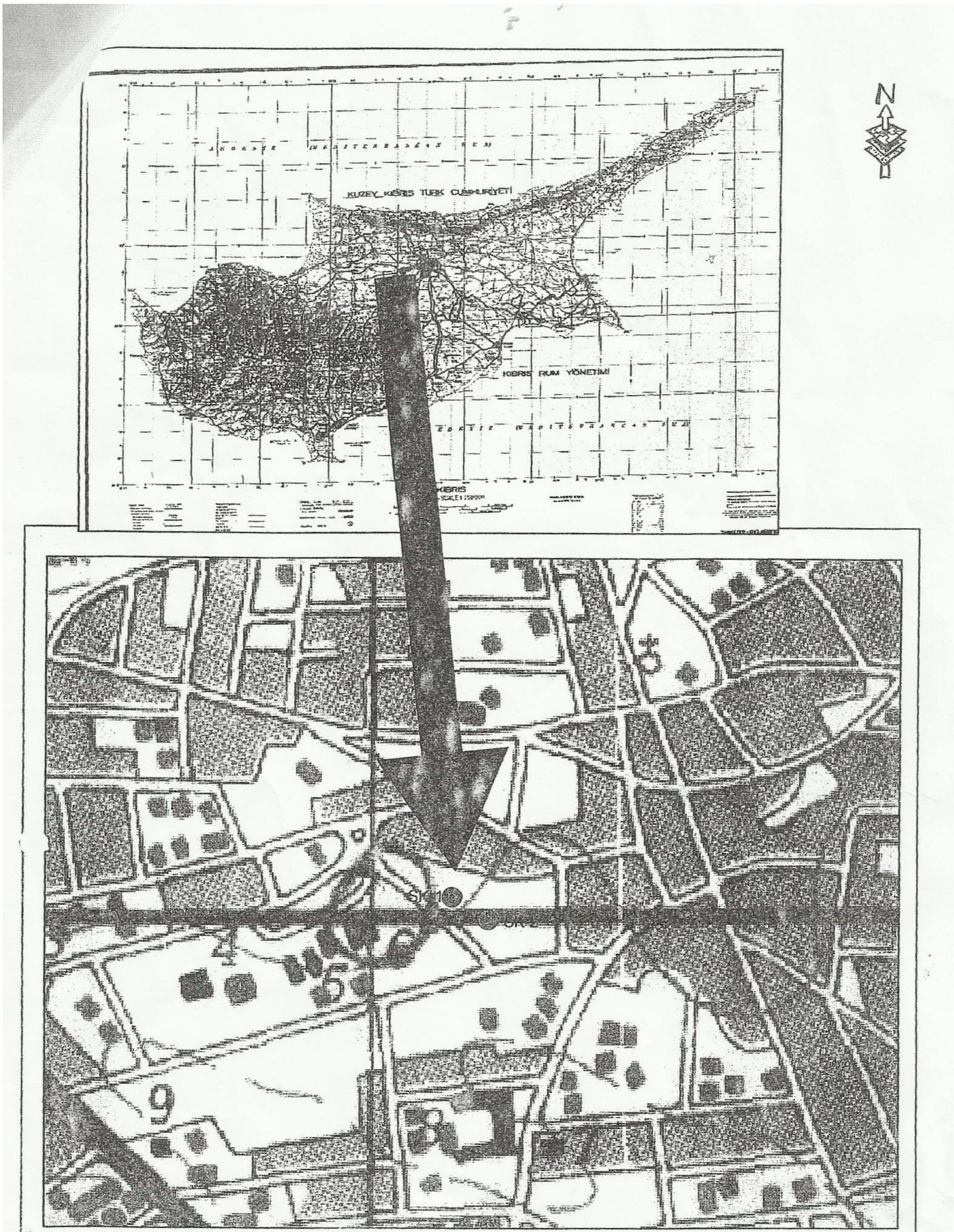
Hazırlayan

Hatice KAŞER

Jeoloji Yüksek Mühendisi

KASIM, 2007

Lefkoşa



ŞEKİL 1 Çalışma Alanının Yer Bulduru Haritası

Temel Zeminine Ait Mekanik Parametreler:

1. İnceleme alanı **2. Derece** deprem bölgesindedir.
2. Temel zemin grubu (**C**)
3. Yerel zemin sınıfı (Z_2)
4. Zeminin spekturum karakteristik periyotları $\mathbf{T_A=0.15sn}$, $\mathbf{T_B=0.40sn}$
5. Kayma dalgası hızı **200-400 m/s** alınabilir.
6. Deprem hesaplarında kullanılacak etkin yer ivmesi katsayısı $\mathbf{A_0 = 0.30}$ 'dur.
7. Yatak Katsayısı $\mathbf{K_0=2000\ ton/m^3}$
8. Bina önem katsayısı **I=1.4**

Hatice Kaşer

Jeoloji Yüksek Mühendisi

APPENDIX -V-

Concrete, formwork and reinforcements amount for 3,4,5,6 and 7 Storey reinforced concrete buildings

1. According to EC8

A1.1. Three Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
1.sto Total	61.16	484.40	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
2.sto Total	61.16	484.40	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
3.sto Total	61.16	484.40	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 576.0 516.1	742.9 0.0 169.0	0.0 789.0 274.2	122.0 164.8 1036.8	2613.0 1529.8 1996.0
1.story Total	2840.1	911.9	1063.2	1323.6	6138.8
2.sto Slab 2.sto Beam 2.sto Column	1761.2 576.0 516.1	690.1 0.0 169.0	0.0 804.2 274.2	122.0 153.4 1036.8	2573.3 1533.6 1996.0
2.story Total	2853.3	859.1	1078.3	1312.2	6102.9
3.sto Slab 3.sto Beam 3.sto Column	1731.0 576.0 516.1	960.9 0.0 169.0	0.0 880.5 274.2	41.6 44.9 962.4	2733.6 1501.5 1921.5
3.story Total	2823.1	1129.9	1154.7	1048.9	6156.6
TOTAL	8516.5	2900.8	3296.2	3684.7	18198.3

A1.2. Four Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
1.sto Total	62.57	495.64	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
2.sto Total	62.57	495.64	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
3.sto Total	62.57	495.64	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
4.sto Total	62.57	495.64	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 572.1 569.9	742.9 0.0 169.0	0.0 916.4 274.2	122.0 41.0 1244.2	2613.0 1529.5 2257.2
1.story Total	2890.0	911.9	1190.5	1407.2	6499.6
2.sto Slab 2.sto Beam 2.sto Column	1707.3 572.1 569.9	742.9 0.0 169.0	0.0 938.4 274.2	122.0 39.1 1244.2	2572.2 1549.5 2257.2
2.story Total	2849.2	911.9	1212.5	1405.3	6478.9
3.sto Slab 3.sto Beam 3.sto Column	1707.3 572.1 569.9	742.9 0.0 169.0	0.0 954.0 274.2	122.0 27.4 1244.2	2572.2 1553.5 2257.2
3.story Total	2849.2	911.9	1228.2	1393.6	6482.9
4.sto Slab 4.sto Beam 4.sto Column	1707.3 574.3 569.9	742.9 0.0 159.0	0.0 781.3 274.2	122.0 161.3 1154.8	2572.2 1517.0 2157.9
4.story Total	2851.5	902.0	1055.5	1438.2	6247.1
TOTAL	11440.0	3637.7	4686.7	5644.3	25608.6

A1.3. Five Storey Building

Story	Concrete m³	R.C.Form m²	Ribbed m³
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 561.4 620.5	690.1 0.0 169.0	0.0 891.3 274.2	122.0 119.1 1225.3	2614.2 1571.7 2288.9
1.story Total	2984.0	859.1	1165.4	1466.4	6474.8
2.sto Slab 2.sto Beam 2.sto Column	1761.3 561.4 620.5	690.1 0.0 169.0	0.0 839.7 274.2	122.0 227.1 1225.3	2573.4 1628.2 2288.9
2.story Total	2943.2	859.1	1113.9	1574.4	6490.6
3.sto Slab 3.sto Beam 3.sto Column	1761.3 562.0 620.5	690.1 0.0 169.0	0.0 917.6 274.2	122.0 151.0 1225.3	2573.4 1630.6 2288.9
3.story Total	2943.8	859.1	1191.7	1498.3	6492.9
4.sto Slab 4.sto Beam 4.sto Column	1761.3 562.5 620.5	690.1 0.0 159.0	0.0 902.3 274.2	122.0 145.6 1225.3	2573.4 1610.4 2279.0
4.story Total	2944.4	849.1	1176.4	1492.9	6462.8
5.sto Slab 5.sto Beam 5.sto Column	1761.3 561.4 620.5	690.1 0.0 169.0	0.0 834.0 274.2	122.0 105.3 1137.3	2573.4 1500.7 2201.0
5.story Total	2943.2	859.1	1108.2	1364.7	6275.1
TOTAL	14758.7	4285.4	5755.6	7396.7	32496.3

A1.4. Six Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00
6.sto Slabs 6.sto Beams 6.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
6.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 561.4 620.5	690.1 0.0 169.0	0.0 887.9 380.4	122.0 172.5 1225.3	2614.2 1621.9 2395.2
1.story Total	2984.0	859.1	1268.3	1519.9	6631.2
2.sto Slab 2.sto Beam 2.sto Column	1761.3 530.0 620.5	690.1 42.0 169.0	0.0 841.7 377.0	122.0 333.4 1225.3	2573.4 1747.1 2391.8
2.story Total	2911.9	901.1	1218.6	1680.7	6712.3
3.sto Slab 3.sto Beam 3.sto Column	1761.3 533.4 620.5	690.1 42.0 169.0	0.0 899.5 274.2	122.0 293.0 1225.3	2573.4 1767.9 2288.9
3.story Total	2915.2	901.1	1173.7	1640.3	6630.3
4.sto Slab 4.sto Beam 4.sto Column	1761.3 534.5 620.5	690.1 42.0 159.0	0.0 866.9 274.2	122.0 276.0 1225.3	2573.4 1719.5 2279.0
4.story Total	2916.3	891.1	1141.1	1623.4	6571.9
5.sto Slab 5.sto Beam 5.sto Column	1761.3 535.6 620.5	690.1 42.0 169.0	0.0 886.3 274.2	122.0 205.2 1225.3	2573.4 1669.1 2288.9
5.story Total	2917.5	901.1	1160.4	1552.5	6531.4
6.sto Slab 6.sto Beam 6.sto Column	1735.5 562.5 620.5	716.5 0.0 169.0	0.0 911.8 274.2	122.0 54.6 1137.3	2574.0 1528.9 2201.0
6.story Total	2918.5	885.5	1186.0	1313.9	6303.9
TOTAL TOTAL	17563.4 17563.4	5338.9 5338.9	7148.0 7148.0	9330.6 9330.6	39381.0 39381.0

A1.5. Seven Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs	32.24	213.18	0.00
1.sto Beams	14.61	118.46	
1.sto Columns	17.06	174.73	
1.sto Total	63.91	506.36	0.00
2.sto Slabs	32.24	213.18	0.00
2.sto Beams	14.61	118.46	
2.sto Columns	17.06	174.73	
2.sto Total	63.91	506.36	0.00
3.sto Slabs	32.24	213.18	0.00
3.sto Beams	14.61	118.46	
3.sto Columns	17.06	174.73	
3.sto Total	63.91	506.36	0.00
4.sto Slabs	32.24	213.18	0.00
4.sto Beams	14.61	118.46	
4.sto Columns	17.06	174.73	
4.sto Total	63.91	506.36	0.00
5.sto Slabs	32.24	213.18	0.00
5.sto Beams	14.61	118.46	
5.sto Columns	17.06	174.73	
5.sto Total	63.91	506.36	0.00
6.sto Slabs	32.24	213.18	0.00
6.sto Beams	14.61	118.46	
6.sto Columns	16.72	171.30	
6.sto Total	63.58	502.93	0.00
7.sto Slabs	32.24	213.18	0.00
7.sto Beams	14.61	118.46	
7.sto Columns	16.73	171.30	
7.sto Total	63.58	502.93	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab	1802.0	690.1	0.0	122.0	2614.2
1.sto Beam	561.4	0.0	884.7	185.2	1631.3
1.sto Column	620.5	169.0	380.4	1225.3	2395.2
1.story Total	2984.0	859.1	1265.1	1532.5	6640.7
2.sto Slab	1761.3	690.1	0.0	122.0	2573.4
2.sto Beam	532.3	42.0	874.7	345.1	1794.1
2.sto Column	620.5	169.0	325.6	1225.3	2340.4
2.story Total	2914.1	901.1	1200.3	1692.4	6707.9
3.sto Slab	1761.3	690.1	0.0	122.0	2573.4
3.sto Beam	536.8	42.0	957.4	305.7	1841.9
3.sto Column	620.5	169.0	274.2	1225.3	2288.9
3.story Total	2918.6	901.1	1231.6	1653.0	6704.3
4.sto Slab	1761.3	690.1	0.0	122.0	2573.4
4.sto Beam	512.7	75.3	883.3	344.8	1816.2
4.sto Column	620.5	159.0	274.2	1225.3	2279.0
4.story Total	2894.5	924.4	1157.5	1692.2	6668.6
5.sto Slab	1761.3	690.1	0.0	122.0	2573.4
5.sto Beam	512.7	76.2	857.1	319.6	1765.6
5.sto Column	620.5	169.0	274.2	1225.3	2288.9
5.story Total	2894.5	935.2	1131.3	1667.0	6628.0
6.sto Slab	1754.1	782.7	0.0	63.7	2600.5
6.sto Slab	1754.1	782.7	0.0	63.7	2600.5
6.sto Beam	512.7	76.2	845.2	277.4	1711.4
6.sto Column	620.5	159.0	269.9	1206.5	2255.9
6.story Total	2887.3	1017.8	1115.1	1547.6	6567.8
7.sto Slab	1754.1	782.7	0.0	63.7	2600.5
7.sto Beam	565.9	0.0	871.5	110.9	1548.3
7.sto Column	620.5	159.0	269.9	1118.5	2167.9
7.story Total	2940.6	941.7	1141.4	1293.1	6316.7
TOTAL	20433.6	6480.4	8242.2	11077.7	46333.9

2. According to TEC-2007 (Case I)

A2.1. Three Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
1.sto Total	61.16	484.40	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
2.sto Total	61.16	484.40	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
3.sto Total	61.16	484.40	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 576.0 617.9	742.9 0.0 0.0	0.0 862.1 274.2	122.0 90.2 1036.8	2613.0 1528.3 1928.8
1.story Total	2941.9	742.9	1136.3	1249.0	6070.1
2.sto Slab 2.sto Beam 2.sto Column	1707.3 576.0 617.9	742.9 0.0 0.0	0.0 790.2 274.2	122.0 161.9 1036.8	2572.2 1528.1 1928.8
2.story Total	2901.1	742.9	1064.4	1320.7	6029.2
3.sto Slab 3.sto Beam 3.sto Column	1707.3 576.0 617.9	742.9 0.0 0.0	0.0 879.7 274.2	122.0 44.9 962.4	2572.2 1500.6 1854.4
3.story Total	2901.1	742.9	1153.8	1129.3	5927.2
TOTAL	8744.1	2228.8	3354.5	3699.1	18026.5

A2.2. Four Storey Building

Story	Concrete m³	R.C.Form m²	Ribbed m³
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
1.sto Total	62.57	495.64	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
2.sto Total	62.57	495.64	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
3.sto Total	62.57	495.64	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
4.sto Total	62.57	495.64	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 572.1 569.9	742.9 0.0 169.0	0.0 916.4 274.2	122.0 41.0 1244.2	2613.0 1529.5 2257.2
1.story Total	2890.0	911.9	1190.5	1407.2	6399.6
2.sto Slab 2.sto Beam 2.sto Column	1707.3 572.1 569.9	742.9 0.0 169.0	0.0 938.4 274.2	122.0 39.1 1244.2	2572.2 1549.5 2257.2
2.story Total	2849.2	911.9	1212.5	1405.3	6378.9
3.sto Slab 3.sto Beam 3.sto Column	1707.3 572.1 569.9	742.9 0.0 169.0	0.0 954.0 274.2	122.0 27.4 1244.2	2572.2 1553.5 2257.2
3.story Total	2849.2	911.9	1228.2	1393.6	6382.9
4.sto Slab 4.sto Beam 4.sto Column	1707.3 574.3 569.9	742.9 0.0 159.0	0.0 781.3 274.2	122.0 161.3 1154.8	2572.2 1517.0 2157.9
4.story Total	2851.5	902.0	1055.5	1438.2	6247.1
TOTAL	11440.0	3637.7	4686.7	5644.3	25408.6

A2. 3. Five Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 561.4 620.5	718.6 0.0 169.0	0.0 881.1 274.2	122.0 142.5 1225.3	2642.6 1585.0 2288.9
1.story Total	2984.0	887.5	1155.3	1489.8	6516.6
2.sto Slab 2.sto Beam 2.sto Column	1761.3 561.4 620.5	746.9 0.0 169.0	0.0 881.6 274.2	122.0 210.1 1225.3	2630.3 1653.1 2288.9
2.story Total	2943.2	915.9	1155.7	1557.5	6572.3
3.sto Slab 3.sto Beam 3.sto Column	1761.3 562.0 620.5	746.9 0.0 169.0	0.0 891.2 274.2	122.0 183.3 1225.3	2630.3 1636.5 2288.9
3.story Total	2943.8	915.9	1165.3	1530.7	6555.7
4.sto Slab 4.sto Beam 4.sto Column	1761.3 562.0 620.5	746.9 0.0 159.0	0.0 885.3 274.2	122.0 160.0 1225.3	2630.3 1607.3 2279.0
4.story Total	2943.8	906.0	1159.4	1507.3	6516.5
5.sto Slab 5.sto Beam 5.sto Column	1761.3 564.2 620.5	746.9 0.0 169.0	0.0 881.6 274.2	122.0 59.7 1137.3	2630.3 1505.5 2201.0
5.story Total	2946.0	915.9	1155.7	1319.0	6336.7
TOTAL	14760.9	4541.2	5791.5	7404.3	32407.8

A2.4. Six Storey Building

Story	Concrete m³	R.C.Form m²	Ribbed m³
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00
6.sto Slabs 6.sto Beams 6.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
6.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 561.4 620.5	718.6 0.0 169.0	0.0 896.9 274.2	122.0 142.3 1225.3	2642.6 1600.6 2288.9
1.story Total	2984.0	887.5	1171.0	1489.6	6532.2
2.sto Slab 2.sto Beam 2.sto Column	1761.3 562.0 620.5	746.9 0.0 169.0	0.0 903.2 274.2	122.0 217.1 1225.3	2630.3 1682.2 2288.9
2.story Total	2943.8	915.9	1177.3	1564.4	6601.4
3.sto Slab 3.sto Beam 3.sto Column	1761.3 532.3 620.5	746.9 42.0 169.0	0.0 878.6 274.2	122.0 257.5 1225.3	2630.3 1710.4 2288.9
3.story Total	2914.1	957.9	1152.7	1604.8	6629.6
4.sto Slab 4.sto Beam 4.sto Column	1761.3 565.9 620.5	746.9 0.0 159.0	0.0 887.4 274.2	122.0 209.4 1225.3	2630.3 1662.8 2279.0
4.story Total	2947.7	906.0	1161.6	1556.8	6572.0
5.sto Slab 5.sto Beam 5.sto Column	1761.3 566.5 620.5	746.9 0.0 169.0	0.0 877.8 274.2	122.0 173.7 1225.3	2630.3 1618.0 2288.9
5.story Total	2948.3	915.9	1152.0	1521.0	6537.2
6.sto Slab 6.sto Beam 6.sto Column	1735.5 562.0 620.5	773.4 0.0 169.0	0.0 888.1 274.2	122.0 68.7 1137.3	2630.8 1518.8 2201.0
6.story Total	2918.0	942.3	1162.3	1328.1	6350.6
TOTAL	17655.9	5525.5	6976.9	9064.7	39223.0

A2.5. Seven Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs	32.24	213.18	0.00
1.sto Beams	14.61	118.46	
1.sto Columns	17.06	174.73	
1.sto Total	63.91	506.36	0.00
2.sto Slabs	32.24	213.18	0.00
2.sto Beams	14.61	118.46	
2.sto Columns	17.06	174.73	
2.sto Total	63.91	506.36	0.00
3.sto Slabs	32.24	213.18	0.00
3.sto Beams	14.61	118.46	
3.sto Columns	17.06	174.73	
3.sto Total	63.91	506.36	0.00
4.sto Slabs	32.24	213.18	0.00
4.sto Beams	14.61	118.46	
4.sto Columns	17.06	174.73	
4.sto Total	63.91	506.36	0.00
5.sto Slabs	32.24	213.18	0.00
5.sto Beams	14.61	118.46	
5.sto Columns	17.06	174.73	
5.sto Total	63.91	506.36	0.00
6.sto Slabs	32.24	213.18	0.00
6.sto Beams	14.61	118.46	
6.sto Columns	16.72	171.30	
6.sto Total	63.58	502.93	0.00
7.sto Slabs	32.24	213.18	0.00
7.sto Beams	14.61	118.46	
7.sto Columns	16.73	171.30	
7.sto Total	63.58	502.93	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab	1802.0	718.6	0.0	122.0	2642.6
1.sto Beam	561.4	0.0	890.7	158.3	1610.4
1.sto Column	620.5	169.0	274.2	1225.3	2288.9
1.story Total	2984.0	887.5	1164.9	1505.6	6542.0
2.sto Slab	1761.3	746.9	0.0	122.0	2630.3
2.sto Beam	530.0	42.0	874.2	281.5	1727.9
2.sto Column	620.5	169.0	274.2	1225.3	2288.9
2.story Total	2911.9	957.9	1148.4	1628.9	6647.1
3.sto Slab	1761.3	746.9	0.0	122.0	2630.3
3.sto Beam	534.0	42.0	878.2	309.5	1763.7
3.sto Column	620.5	169.0	274.2	1225.3	2288.9
3.story Total	2915.8	957.9	1152.3	1656.8	6682.9
4.sto Slab	1761.3	746.9	0.0	122.0	2630.3
4.sto Beam	537.3	42.0	862.8	300.0	1742.1
4.sto Column	620.5	159.0	274.2	1225.3	2279.0
4.story Total	2919.1	948.0	1137.0	1647.3	6651.4
5.sto Slab	1761.3	746.9	0.0	122.0	2630.3
5.sto Beam	488.6	110.3	871.1	233.8	1703.8
5.sto Column	620.5	169.0	274.2	1225.3	2288.9
6.sto Slab	1754.1	782.7	0.0	63.7	2600.5
6.sto Slab	1754.1	782.7	0.0	63.7	2600.5
6.sto Beam	521.1	71.8	902.3	165.7	1660.9
6.sto Column	620.5	169.0	274.2	1225.3	2288.9
6.story Total	2895.7	1023.4	1176.5	1454.7	6550.4
7.sto Slab	1754.1	782.7	0.0	63.7	2600.5
7.sto Beam	565.9	0.0	884.5	83.8	1534.2
7.sto Column	620.5	159.0	274.2	1137.3	2191.0
7.story Total	2940.6	941.7	1158.7	1284.9	6325.8
TOTAL	20437.5	6742.6	8082.9	10759.3	46022.4

3. According to TEC-2007 (Case II)

A3.1. Three Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
1.sto Total	61.16	484.40	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
2.sto Total	61.16	484.40	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 15.15 13.77	213.18 122.81 148.41	0.00
3.sto Total	61.16	484.40	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 576.0 617.9	742.9 0.0 0.0	0.0 873.9 274.2	122.0 93.1 1036.8	2613.0 1543.0 1928.8
1.story Total	2941.9	742.9	1148.0	1251.9	6084.8
2.sto Slab 2.sto Beam 2.sto Column	1707.3 576.0 617.9	742.9 0.0 0.0	0.0 814.8 274.2	122.0 158.5 1036.8	2572.2 1549.3 1928.8
2.story Total	2901.1	742.9	1089.0	1317.3	6050.3
3.sto Slab 3.sto Beam 3.sto Column	1707.3 576.0 617.9	742.9 0.0 0.0	0.0 879.7 274.2	122.0 49.7 962.4	2572.2 1505.4 1854.4
3.story Total	2901.1	742.9	1153.9	1134.1	5932.0
TOTAL	8744.1	2228.8	3390.9	3703.3	18067.1

A3.2. Four Storey Building

Story	Concrete m³	R.C.Form m²	Ribbed m³
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
1.sto Total	62.57	495.64	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
2.sto Total	62.57	495.64	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
3.sto Total	62.57	495.64	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.88 15.45	213.18 120.59 161.87	0.00
4.sto Total	62.57	495.64	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1748.0 572.1 569.9	742.9 0.0 178.9	0.0 924.6 377.0	122.0 76.4 1244.2	2613.0 1573.0 2369.9
1.story Total	2890.0	921.8	1301.5	1442.5	6555.9
2.sto Slab 2.sto Beam 2.sto Column	1707.3 572.1 569.9	742.9 0.0 169.0	0.0 933.4 325.6	122.0 103.3 1244.2	2572.2 1608.8 2308.6
2.story Total	2849.2	911.9	1259.0	1469.4	6489.6
3.sto Slab 3.sto Beam 3.sto Column	1707.3 572.6 569.9	742.9 0.0 169.0	0.0 934.8 274.2	122.0 97.6 1244.2	2572.2 1605.0 2257.2
3.story Total	2849.8	911.9	1208.9	1463.8	6434.5
4.sto Slab 4.sto Beam 4.sto Column	1707.3 572.1 569.9	742.9 0.0 159.0	0.0 796.2 274.2	122.0 163.0 1154.8	2572.2 1531.3 2157.9
4.story Total	2849.2	902.0	1070.4	1439.8	6261.4
TOTAL	11438.3	3647.6	4839.9	5815.6	25741.4

A3.3. Five Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 561.4 620.5	690.1 0.0 298.2	0.0 862.8 507.2	122.0 290.3 1225.3	2614.2 1714.5 2651.2
1.story Total	2984.0	988.3	1370.0	1637.6	6979.9
2.sto Slab 2.sto Beam 2.sto Column	1761.3 502.6 620.5	690.1 80.5 169.0	0.0 866.7 377.0	122.0 449.4 1225.3	2573.4 1899.3 2391.8
2.story Total	2884.4	939.6	1243.7	1796.8	6864.5
3.sto Slab 3.sto Beam 3.sto Column	1761.3 504.8 620.5	690.1 80.5 169.0	0.0 913.2 325.6	122.0 378.2 1225.3	2573.4 1876.7 2340.4
3.story Total	2886.7	939.6	1238.7	1725.5	6790.5
4.sto Slab 4.sto Beam 4.sto Column	1761.3 534.0 620.5	690.1 42.0 159.0	0.0 889.6 274.2	122.0 308.5 1225.3	2573.4 1774.2 2279.0
4.story Total	2915.8	891.1	1163.8	1655.9	6626.6
5.sto Slab 5.sto Beam 5.sto Column	1761.3 562.0 620.5	690.1 0.0 169.0	0.0 936.1 274.2	122.0 73.8 1163.6	2573.4 1571.8 2227.2
5.story Total	2943.8	859.1	1210.2	1359.4	6372.5
TOTAL	14614.7	4617.7	6226.4	8175.1	33633.9

A3.4. Six Storey Building

Story	Concrete m^3	R.C.Form m^2	Ribbed m^3
1.sto Slabs	32.24	213.18	0.00
1.sto Beams	14.61	118.46	
1.sto Columns	17.06	174.73	
1.sto Total	63.91	506.36	0.00
2.sto Slabs	32.24	213.18	0.00
2.sto Beams	14.61	118.46	
2.sto Columns	17.06	174.73	
2.sto Total	63.91	506.36	0.00
3.sto Slabs	32.24	213.18	0.00
3.sto Beams	14.61	118.46	
3.sto Columns	17.06	174.73	
3.sto Total	63.91	506.36	0.00
4.sto Slabs	32.24	213.18	0.00
4.sto Beams	14.61	118.46	
4.sto Columns	17.06	174.73	
4.sto Total	63.91	506.36	0.00
5.sto Slabs	32.24	213.18	0.00
5.sto Beams	14.61	118.46	
5.sto Columns	17.06	174.73	
5.sto Total	63.91	506.36	0.00
6.sto Slabs	32.24	213.18	0.00
6.sto Beams	14.61	118.46	
6.sto Columns	17.06	174.73	
6.sto Total	63.91	506.36	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab	1802.0	690.1	0.0	122.0	2614.2
1.sto Beam	561.4	0.0	846.9	351.7	1760.1
1.sto Column	620.5	337.9	503.8	1225.3	2687.5
1.story Total	2984.0	1028.0	1350.7	1699.1	7061.8
2.sto Slab	1761.3	690.1	0.0	122.0	2573.4
2.sto Beam	504.3	80.5	922.6	465.1	1972.5
2.sto Column	620.5	188.8	377.0	1225.3	2411.6
2.story Total	2886.1	959.5	1299.5	1812.4	6957.5
3.sto Slab	1761.3	690.1	0.0	122.0	2573.4
3.sto Beam	459.4	148.8	943.5	462.8	2014.6
3.sto Column	620.5	169.0	325.6	1225.3	2340.4
3.story Total	2841.3	1007.9	1269.0	1810.2	6928.3
4.sto Slab	1761.3	690.1	0.0	122.0	2573.4
4.sto Beam	459.4	151.5	872.5	454.4	1937.8
4.sto Column	620.5	159.0	274.2	1225.3	2279.0
4.story Total	2841.3	1000.6	1146.6	1801.8	6790.2
5.sto Slab	1761.3	690.1	0.0	122.0	2573.4
5.sto Beam	488.6	111.2	884.1	314.0	1797.9
5.sto Column	620.5	169.0	274.2	1225.3	2288.9
5.story Total	2870.4	970.2	1158.3	1661.4	6660.3
6.sto Slab	1735.5	716.5	0.0	122.0	2574.0
6.sto Beam	565.3	0.0	921.3	103.2	1589.9
6.sto Column	620.5	169.0	274.2	1172.3	2236.0
6.story Total	2921.3	885.5	1195.5	1397.6	6399.9
TOTAL	17344.4	5851.7	7419.6	10182.3	40798.0

A3.5. Seven Storey Building

Story	Concrete m³	R.C.Form m²	Ribbed m³
1.sto Slabs 1.sto Beams 1.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
1.sto Total	63.91	506.36	0.00
2.sto Slabs 2.sto Beams 2.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
2.sto Total	63.91	506.36	0.00
3.sto Slabs 3.sto Beams 3.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
3.sto Total	63.91	506.36	0.00
4.sto Slabs 4.sto Beams 4.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
4.sto Total	63.91	506.36	0.00
5.sto Slabs 5.sto Beams 5.sto Columns	32.24 14.61 17.06	213.18 118.46 174.73	0.00
5.sto Total	63.91	506.36	0.00
6.sto Slabs 6.sto Beams 6.sto Columns	32.24 14.61 16.72	213.18 118.46 171.30	0.00
6.sto Total	63.58	502.93	0.00
7.sto Slabs 7.sto Beams 7.sto Columns	32.24 14.61 16.73	213.18 118.46 171.30	0.00
7.sto Total	63.58	502.93	0.00

Story no	ø8 kg	ø10 kg	ø12 kg	ø14 kg	TOTAL kg
1.sto Slab 1.sto Beam 1.sto Column	1802.0 545.2 620.5	690.1 21.0 298.2	0.0 858.6 459.2	122.0 354.6 1225.3	2614.2 1779.5 2603.2
1.story Total	2967.8	1009.3	1317.8	1702.0	6996.8
2.sto Slab 2.sto Beam 2.sto Column	1761.3 506.5 620.5	690.1 80.5 169.0	0.0 929.6 377.0	122.0 515.0 1225.3	2573.4 2031.6 2391.8
2.story Total	2888.3	939.6	1306.5	1862.3	6996.8
3.sto Slab 3.sto Beam 3.sto Column	1761.3 459.4 620.5	690.1 156.7 169.0	0.0 970.1 325.6	122.0 522.7 1225.3	2573.4 2109.0 2340.4
3.story Total	2841.3	1015.8	1295.7	1870.0	7022.8
4.sto Slab 4.sto Beam 4.sto Column	1761.3 459.4 620.5	690.1 155.0 159.0	0.0 945.9 274.2	122.0 504.6 1225.3	2573.4 2064.9 2279.0
4.story Total	2841.3	1004.1	1220.0	1851.9	6917.3
5.sto Slab 5.sto Beam 5.sto Column	1761.3 459.4 620.5	690.1 150.6 169.0	0.0 812.4 274.2	122.0 537.1 1234.7	2573.4 1959.5 2298.4
5.story Total	2841.3	1009.6	1086.5	1893.8	6831.3
6.sto Slab 6.sto Slab 6.sto Beam 6.sto Column	1754.1 1754.1 488.6 620.5	782.7 782.7 117.3 159.0	0.0 0.0 822.6 269.9	63.7 63.7 406.7 1215.7	2600.5 2600.5 1835.2 2265.2
6.story Total	2863.3	1059.0	1092.5	1686.2	6700.9
7.sto Slab 7.sto Beam 7.sto Column	1754.1 569.3 620.5	782.7 0.0 159.0	0.0 912.6 269.9	63.7 109.8 1170.1	2600.5 1591.6 2219.5
7.story Total	2943.9	941.7	1182.5	1343.6	6411.7
TOTAL	20187.1	6979.0	8501.6	12209.8	47877.5