T.C.
MUĞLA SITKI KOÇMAN UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF CIVIL ENGINEERING

DIFFERENCES ON THE EARTHQUAKE PERFORMANCES OF EDUCATIONAL BUILDINGS BASED ON SITE SPECIFIC SPECTRA IN MUĞLA PROVINCE

MASTER THESIS

ENGİN ERDOĞAN BAYRAKTAR

SEPTEMBER 2018
MUGLA

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THESIS CONFIRMATION

The thesis, prepared by ***Engin Erdoğan BAYRAKTAR***, titled as "***Differences on the Earthquake Performances of Educational Buildings Based on Site-Specific Spectra in Muğla Province***" has been accepted unanimously/majority by the jury listed below that fulfils necessary conditions for master's degree of Department of Civil Engineering at 19/07/2018.

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I hereby declare that all information contained in this thesis was obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conducts, I have fully cited and referenced all materials and results that are not original to this work.

Engin Erdoğan BAYRAKTAR

19/07/2018

ÖZET

SAHAYA ÖZGÜ SPEKTRUMA GÖRE MUĞLA İLİNDEKİ BAZI EĞİTİM YAPILARININ DEPREM PERFORMANSLARINDAKİ FARKLILIKLAR

Engin Erdoğan BAYRAKTAR

Yüksek Lisans
Fen Bilimleri Enstitüsü
İnşaat Mühendisliği Anabilim Dalı
Tez Danışmanı: Prof. Dr. Recep BİRGÜL
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Bu çalışmada, Muğla ilindeki bazı eğitim binaları için sahaya özgü tasarım spektrumu geliştirilmiştir çünkü tasarım spektrumunun amacı, tasarım ömrü boyunca belirli bir yapı üzerinde karşılaşılabilecek olası deprem yüklerini tahmin etmektir.

Öte yandan, eğitim binalarının bölgelerine göre tasarım spektrumunu elde ederken, TEC-2007'ye ait birinci derece deprem bölgesi katsayıları kullanılmıştır. Ayrıca, bölgeler, belirli yıllar ve beş yer hareketi parametresi (deprem büyüklüğü, tepe yer ivmesi, zamana göre 30m derinliğe kadar ortalama kesme dalgası hızı, fay tipi ve kırılma mesafesi) arasında toplanan verilerle tek tek karakterize edilmiştir.

Sonuç olarak, bu parametrelerle sahaya özgü tasarım spektrumları elde edilmiş ve eğitim binalarının deprem performansının yapısal analizi 50 yıl için %10 aşılma olasılığı olan Hemen Kullanım ve 50 yıl için %2 ile %10 aşılma olasılıkları olan Can Güvenliği sınırları içinde değerlendirilmiştir. Son olarak, sonuçlar TDY-2007'nin tasarım spektrumu ile eşdeğer deprem yükü yöntemi, üst kat köşe yatay deplasmanlar ve yük taşıyıcı elemanların (perde, kolon ve kiriş) analizi ile karşılaştırılmış, olumlu ve olumsuz yönleri belirtilmiştir.

Anahtar Kelimeler: Sahaya Özgü Spektrum, Yer Hareket Parametreleri, Doğrusal Eşdeğer 1-B Yer Tepki Analizi, Doğrusal Elastik Performans Değerlendirmesi, Eşdeğer Deprem Yükü Yöntemi.

ABSTRACT

DIFFERENCES ON THE EARTHQUAKE PERFORMANCES OF EDUCATIONAL BUILDINGS BASED ON SITE SPECIFIC SPECTRA IN MUĞLA PROVINCE

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In this study, site-specific design spectra have been developed for some education buildings in the province of Muğla because the aim of the design spectrum is to estimate of the possible earthquake loads that can be encountered on a given structure during its design life.

On the other hand, first order seismic zone coefficients belonging to TEC-2007 were used when obtaining the design spectrum due to the regions of education buildings. Besides, the regions were individually characterized with the collected data set between specific years and five ground motion parameters (earthquake magnitude, peak ground acceleration, the time-averaged shear-wave velocity to 30m depth, fault type, and rupture distance)

As a result, site-specific design spectra were obtained with these variables, and seismic performance of education buildings were determined for Ready to Use (10% in 50 years) and Life Safety (2% and 10% in 50 years) performance levels. Finally, the results were compared, and their positive and negative aspects were indicated with the analyses of the design spectrum of TEC-2007 with respect to equivalent seismic load method, horizontal displacement of top floor corners, and load-bearing structural elements (Shear wall, column, and beam).

Keywords: Site Specific Spectra, Ground Motion Parameters, Linear Equivalent 1-D Ground Response Analysis, Linear Elastic Performance Evaluation, Equivalent Seismic Load Method

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LIST OF SYMBOLS AND ABBREVIATIONS

A (T)	Spectral Acceleration Coefficient
A_o	Effective Ground Acceleration Coefficient
R	Structural Behavior Factor
R_a(T)	Seismic Load Reduction Factor
S(T)	Spectrum Coefficient
T	Building natural vibration period [s]
T_A ,T_B	Spectrum Characteristic Periods [s]
Vt	In the Equivalent Seismic Load Method, total equivalent seismic load acting on the building (base shear) in the earthquake direction considered
η_{bi}	Torsional Irregularity Factor defined at i'th storey of building
b_w	The body width of the cross section
d	Effective beam and column Height
f_{cm}	Strength of the existing concrete defined according to
f_{ctm}	Tensile strength of the existing concrete defined according to
f_{ck}	Characteristic compressive cylinder strength of concrete
f_{yk}	Characteristic yield strength of longitudinal reinforcement
R_a	Inhibition Coefficient of the Power of Earthquake
ρ	Tension reinforcement ratio
ρ_b	Balanced reinforcement ratio
ρ'	Pressure reinforcement ratio
H_w	Total height of partition measured from under the foundation or from the ground floor
b_w	Width of beam web, thickness of wall web
I_w	Length of partition or piece of strap partition on plan
I_n	Clear height of column between beams, clear span of beam between column or wall faces
V_{dy}	Simple beam – shear force developed at any section of the beam due to vertical loads
V_e	Shear force considered for the calculation of transverse reinforcement of column, beam or Wall
M_{pi}	Positive or negative moment capacity calculated at column face on left end i of a beam by considering f_{ck} , f_{yk} and strain hardening of steel

M_{pj}	Negative or positive moment capacity calculated at column face on right end j of a beam by considering f_{ck}, f_{yk} and strain hardening of steel
M_A	Residual moment capacity
M_D	Moment composed from vertical powers
M_E	Moment consisted under the earthquake power
M_K	Moment capacity calculated in accordance with existing material strength
N_A	Axial power correspond to momentary moment capacity
N_D	Axial power consisted from vertical powers
N_E	Axial power consisted under the earthquake power
N_K	Axial power correspond to cross section moment capacity
r	Ratio of effect/capacity
r_s	The limit value of ratio of effect/capacity
TEC-2007	Turkish Earthquake Code 2007
SSS	Site-Specific Spectrum
SSDS	Site-Specific Design Spectrum
ESLM	Equivalent Seismic Load Method
Str	Structural
RU	Ready to Use
LS	Life Safety
PC	Pre-Collapse
MDZ	Minimum Damage Zone
SDZ	Significant Damage Zone
ADZ	Advanced Damage Zone
CZ	Collapse Zone

1. INTRODUCTION

1.1. Review of Literature

In this study, site specific spectra were developed for educational buildings of which two of them are four storeys and the last one is three storeys. These obtained spectra were compared with the design spectrum prepared in the TEC-2007 regulations and the seismic performances were evaluated. At the same time, the analysis methods used in this study and the detections of content of the modeling are also given below.

In study of Rota *et al.*, in order to obtain the site response spectrum, soil profile was characterized as 1-D with using each layer of thickness, shear wave velocity, unit weight and degradation curves of the shear modulus and of the damping ratio. Also, acceleration time histories were selected from real time records that conform with Eurocode 8. After that, 1-D equivalent linear analysis was done with Shake91 that calculated stress and deformations with selected acceleration time histories to various layers based on outcropping bedrock; thus, response spectrum was obtained with selected acceleration time histories and then site response spectrum was obtained from the average of the response spectra of the seven accelerograms (Rota *et al.*, 2010).

Yoshida *et al*. worked on equivalent linear dynamic response analysis of ground with frequency dependent characteristic of stiffness and damping. In this regard, SHAKE91 overestimated peak acceleration under lower frequency motions and underestimated amplification in high frequency motions because of constant fraction of peak strain in entire earthquake duration (Yoshida *et al.*, 2001).

Fahjan selected ten earthquake records to each soil type with respect to TEC-2007 from Pacific earthquake engineering research data center. The most important findings in linear elastic and non-linear calculation methods are the selection and scaling of appropriate earthquake records. Also, magnitude of earthquakes, fault type, distance from fault, local ground condition and acceleration records must be taken into consideration in order to be able to select earthquake records (Fahjan, 2008).

In the seismic hazard analysis carried out by Harman and Küyük for the province of Sakarya, the spectral acceleration value with 5% damping ratio was calculated for each period defined as attenuation relationship in the first-degree earthquake zone with Z1 soil class and the design spectrum was obtained by taking the average of the attenuation relationship values. The obtained design spectrum is 1.5-2 times higher than the design spectrum of TEC-2007 and as the periods increased, the differences were observed to decrease (Harman and Küyük 2016).

In the study of master thesis of Yılmaz, a 6-storey building projected according to the 1975 earthquake regulations was analyzed with SAP2000v14.2 by linear elastic equivalent earthquake load method and its performance was evaluated for life safety (2% in 50 years) with respect to TEC-2007. When results were examined, Structural members are in collapse zone and for this reason strengthening is necessary (Yılmaz, 2014).

Kılıçer and Özgan have compared the base shear force, column axial forces and vertical displacement with rigid foundation assumption using some soil models in the literature to examine the structure-soil interaction in the design of reinforced concrete structures. This comparison was made under the effect of 1999 Kocaeli earthquake for 12 storeys reinforced concrete building. When looking at the results, increase of earthquake acceleration acting on the structure increases the ground effect at the obtained results (Kılıçer and Özgan, 2018).

Türkay and Güler compared base shear forces with linear and nonlinear methods of evaluating earthquake performance for a 4-storey education building. They have observed that in the nonlinear calculation the base shear force is approximately twice that of the linear base shear force. The reason for this is the plastic joints in the sections that reach their capacities by pushover analysis and increasing the system resistance due to the common use of the remaining sections with loads (Türkay and Güler, 2017).

In study of Türker and Yavaş, they compared the performance evaluation methods (Equivalent seismic load method, incremental equivalent seismic load method and nonlinear time history method) in the Turkish earthquake regulations. With this comparison, a 6-storey frame system was evaluated with an earthquake with a probability of exceeding 10% in 50 years. In addition, damage zones, relative floor displacements and performance levels were compared. When the results are analyzed, the confinement condition is determinant for the damage condition of the structural element in the equivalent seismic load method. Also, equivalent seismic load method does not reveal an unsafe situation in performance evaluations but generally it can be said that the performance evaluations to be done with this method will not be economical because it has given more unfavorable damage cases than the other two methods (Türker and Yavaş, 2011).

The performance analysis of reinforced concrete buildings with different structural properties has been applied by Arısoy and Arel to the 8-storey reinforced concrete frame system and 8-storey reinforced concrete shear wall frame system. On the other hand, equivalent seismic load method and incremental equivalent seismic load method have been used to determine earthquake performance. When the performance of the linear and nonlinear methods is compared, it was observed that the structural performance is at the same level because the torsional irregularity was not present in the structure and the earthquake behavior was defined by a single dominant mode (Arısoy and Arel, 2010).

Uçar and Merter have examined linear (Equivalent seismic load and mode superposition) and nonlinear (time history) methods of earthquake performance with 5, 8 and 10-storey frame system. In this context, the base shear force calculated from the Equivalent seismic load method was approximately 20% greater than the value calculated from the mode superposition method. Also, base shear force obtained from the calculation method in time history was greater than the values obtained from the other two methods because the seismic loads were reduced partially by considering the peculiar nonlinear behavior of the load-bearing system by using the earthquake load reduction coefficient in the linear calculation method, but earthquake accelerations were directly affected by the nonlinear calculation method (Uçar and Merter, 2012).

In Duman's master thesis study, equivalent seismic load and mode superposition methods in performance evaluation of building belonging to 5 and 7-storey buildings were used. When the results were examined, it was seen that equivalent seismic load method leads to more negative results than mode superposition method due to torsional irregularity (Duman, 2011).

In the study of master thesis of Yavuz, performance of an existing education building was evaluated with linear and nonlinear methods at the level of life safety. As a result of their assessment, the structure was below the collapse prevention as performance level due to its low material properties (Yavuz, 2006).

Denizer has evaluated performance of 5 and 7-storey buildings with linear and nonlinear methods and compared the results. In this context, the building performance evaluation made by the equivalent seismic load method was within the life safety limits of TEC-2007 (Denizer, 2012).

In analyses of earthquake performance who was performed by Tuncer, linear (Equivalent seismic load and mode superposition) and nonlinear (incremental equivalent seismic load method and nonlinear time history) methods were used to ready to use (10% in 50 years) and life safety (2% in 50 years) performance levels of 6-storey education building. These methods have also been used for a 2-storey frame system. In the comparison made after the analyses, the internal forces and the effect/capacity ratios in the frame system were similar between linear methods due to the fact that the dominant mode was 1st mode in the 2-storey frame system. On the other hand, when the earthquake performance was examined with linear and nonlinear methods, the education building has not achieved the desired performance levels (Tuncer, 2008).

In the thesis study prepared by Arslan, the building performance of an 8 storeys hospital building was determined by linear and nonlinear methods. As a result, the required performance levels at TEC-2007 could not be reached due to weakness of some beams. For this reason, strengthening of some beams in the lower and middle storeys was proposed (Arslan, 2009).

Looking at the literature reviews, structural analyses of education buildings were not carried out by obtaining site-specific design spectrum for them. Therefore, in this study, site-specific design spectra were obtained for specific education buildings and these were used in structural analyses for performance evaluation of education buildings.

1.2. The Aim of the Thesis

Determination of earthquake performance of existing reinforced concrete structures is an important issue in current civil engineering problems. Earthquake performance is defined as safety of the structure determined by the level and distribution of the damage that can occur in a building under the effect of a predeterminal earthquake. In this context, earthquake performances of existing buildings should be determined in order to reduce possible earthquake damages in future.

TEC-2007 has made a great contribution to earthquake engineering in Turkey. The equivalent seismic load method, which is one of the linear elastic analysis methods in TEC-2007, has been made to compare the ratio of the effects of the earthquake excitations to the element capacities of the structural system elements with the limit values determined in TEC-2007.

On the other hand, within the aim of this thesis study, educational buildings that were designed by regarding TEC-1975 were analyzed with equivalent seismic load method and design spectrum of TEC-2007 to base shear forces, top floor corner displacements and the probability of exceeding the building performance in 50 years at 10% (RU-LS) and 2% (LS) were evaluated for earthquake. At the same time, applying the site-specific design spectrum to the same structures, these three conditions are re-evaluated and compared with each other. In addition, seven different acceleration records were used when the site-specific design spectrum was obtained. Also, structural analyses were carried out after defining site-specific design spectrum to system of Probina Orion 2013 and the results were evaluated on the basis of structural elements.

2. ANALYSIS METHODS

2.1. Ground Response Analysis with SHAKE91

Soil profiles were obtained from 20-meter drilling records of three specified education buildings; as shown in Table 2.1. soil profiles were characterized as 1-D with using their information of thickness of each layer, plasticity index, unit weight, shear wave velocity (V_s), and shear wave velocity to a depth of 30 meters (V_{s30}).

Table 2.1. Properties of Characterized Soil Profiles

	Education Building-A		Education Building-B		Education Building-C	
Depth	0-10m	10-20m	0-10m	10-20m	0-5m	5-20m
Soil	Clay	Clay	Sand	Sand	Clay	Sand
Plasticity Index	17	16	NP	NP	32	NP
$\gamma_{natural}$ (g/cm^3)	1.89	1.91	2.02	2.07	1.89	1.96
V_s (m/s)	200	213	410	508	185	538
V_{s30} (m/s)	209.8		467.8		508.9	

On the other hand, different shear modulus reduction and damping curves as shown in Figure 2.1. – 2.6. were used according to the soil types and plasticity index for the SHAKE91 analyses in the soil profiles of the three education buildings chosen to obtain site response spectra (PEER center, 2016).

- For education building A, Vucetic's and Dobry's curves were used for clayey layer 1 and 2, which depend on their plasticity index value to shear modulus reduction and damping curves (Vucetic and Dobry, 1991)
- For education building B, Seed's and Idriss's curves were used for sandy layer 1 and 2 due to non-plastic soil type to average shear modulus reduction and damping curves. (Seed and Idriss, 1991)
- For education building C, Vucetic's and Dobry's curves were used for clayey layer 1 and Seed's & Idriss's curves were used for sandy layer 2 due to different type of soil layers to shear modulus reduction and damping curves.
- For all three education buildings, Idriss's curves were used for shear modulus reduction and damping curves of bedrock. (Idriss and Sun, 1992)

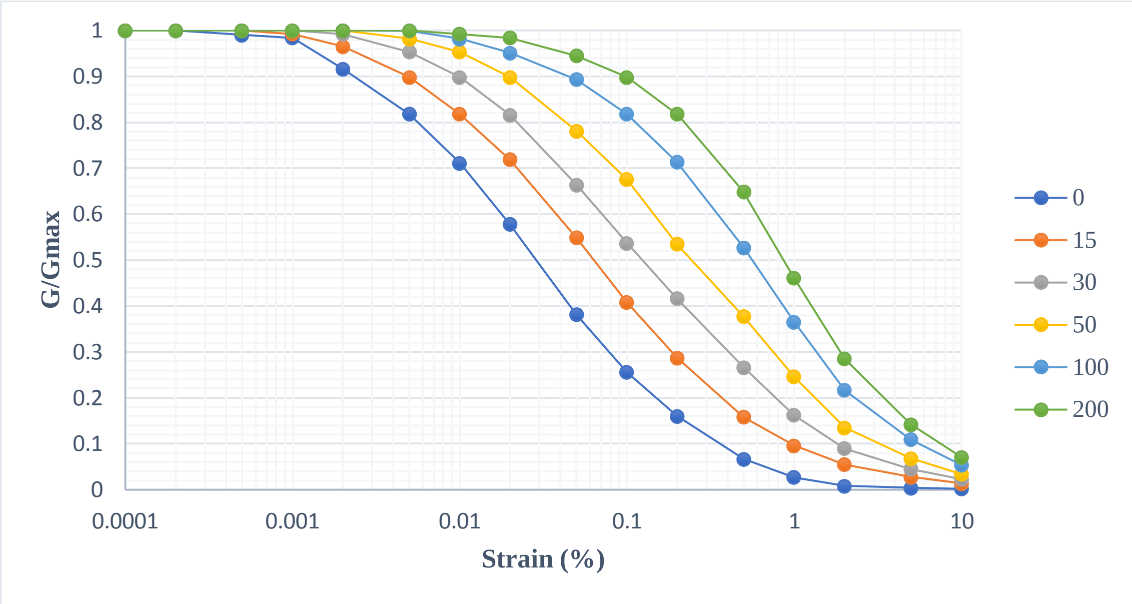

Figure 2.1. Shear Modulus Reduction Curves of Vucetic & Dobry

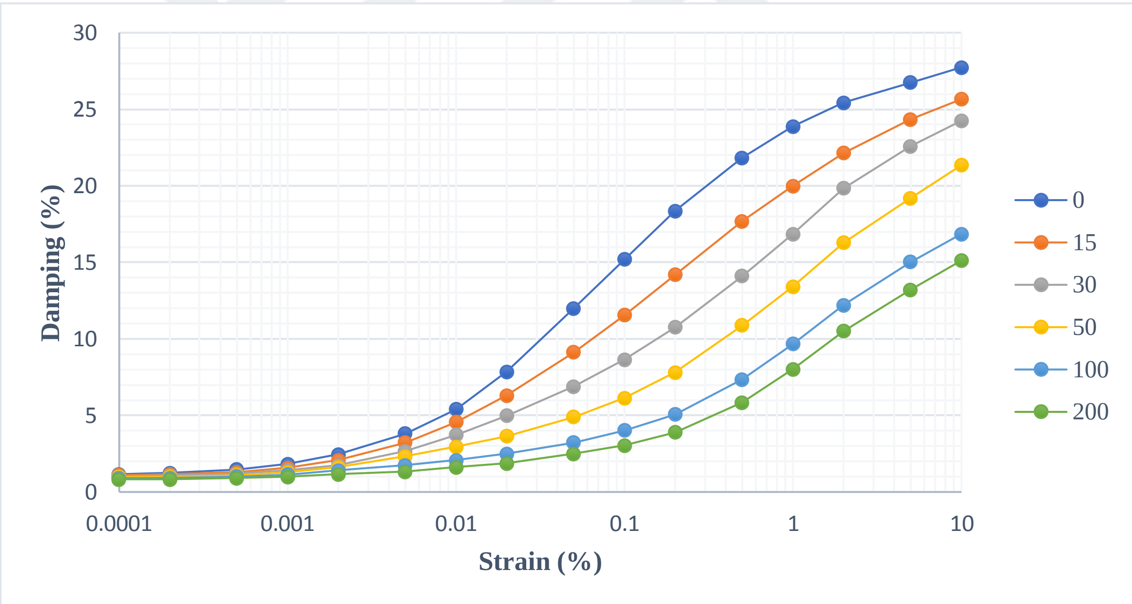

Figure 2.2. Damping Ratio Curves of Vucetic & Dobry

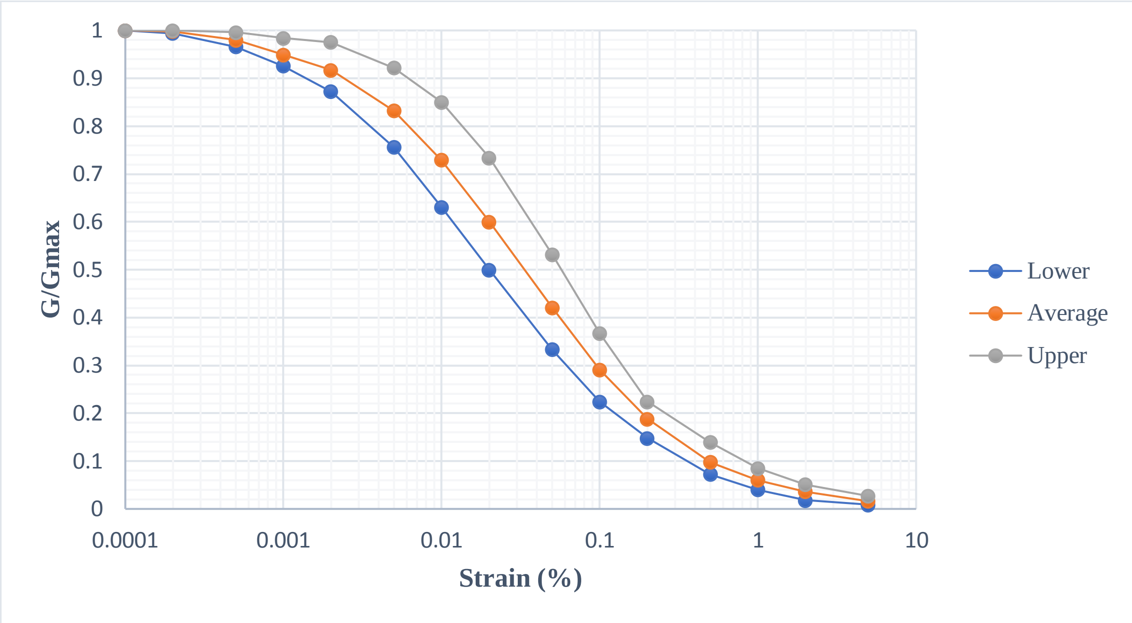

Figure 2.3. Shear Modulus Reduction Curves of Seed & Idriss

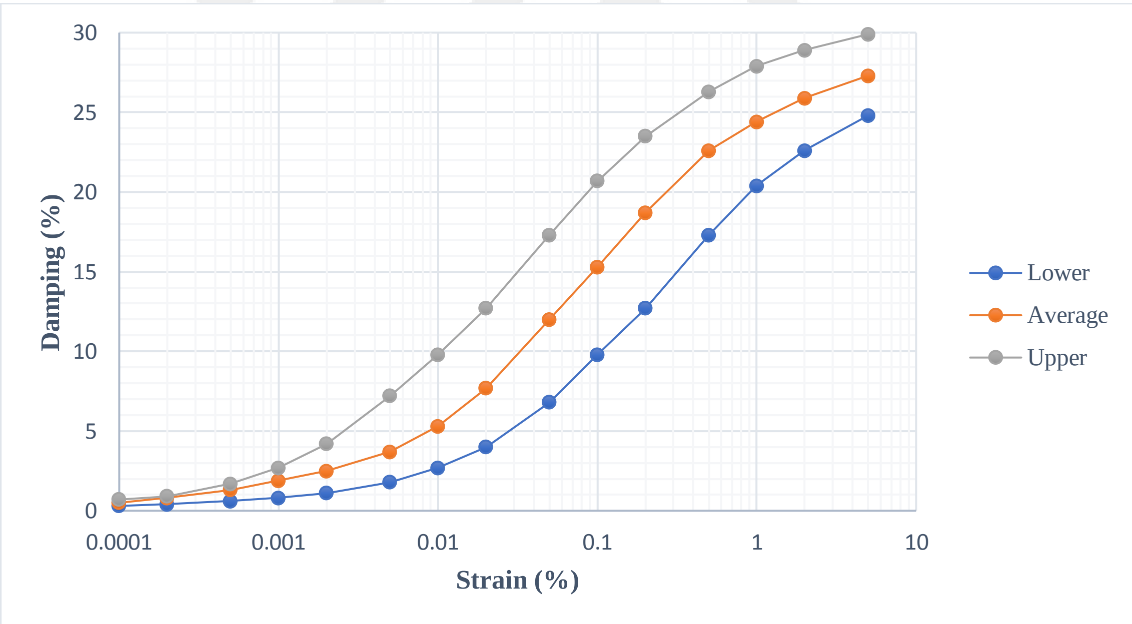

Figure 2.3. Damping Ratio Curves of Seed & Idriss

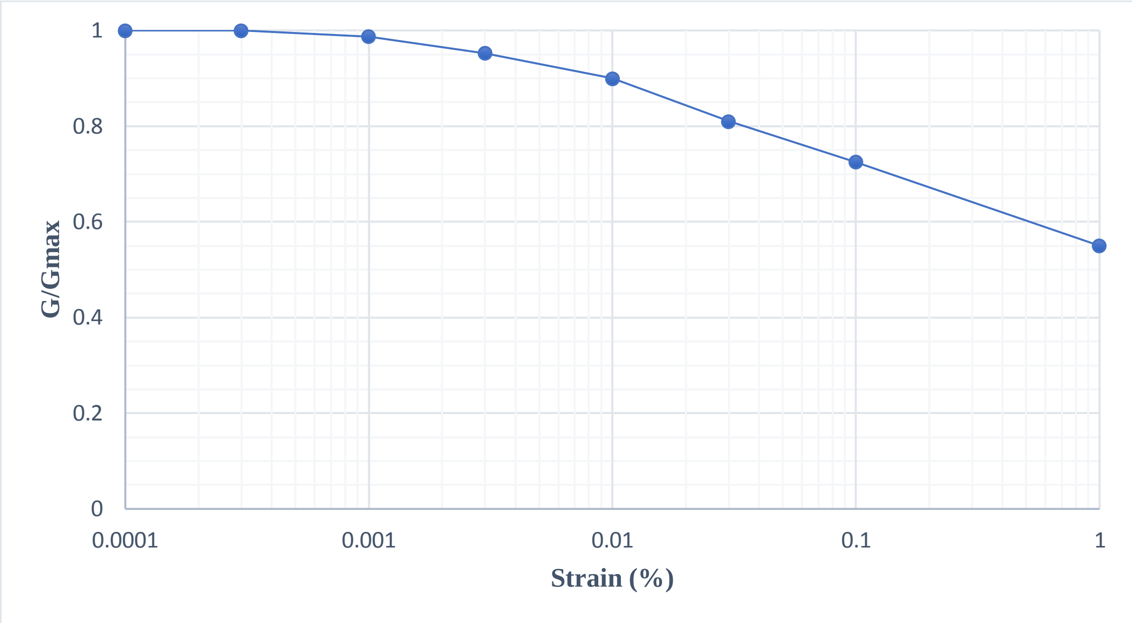

Figure 2.4. Shear Modulus Reduction Curve of Idriss for Rock Material

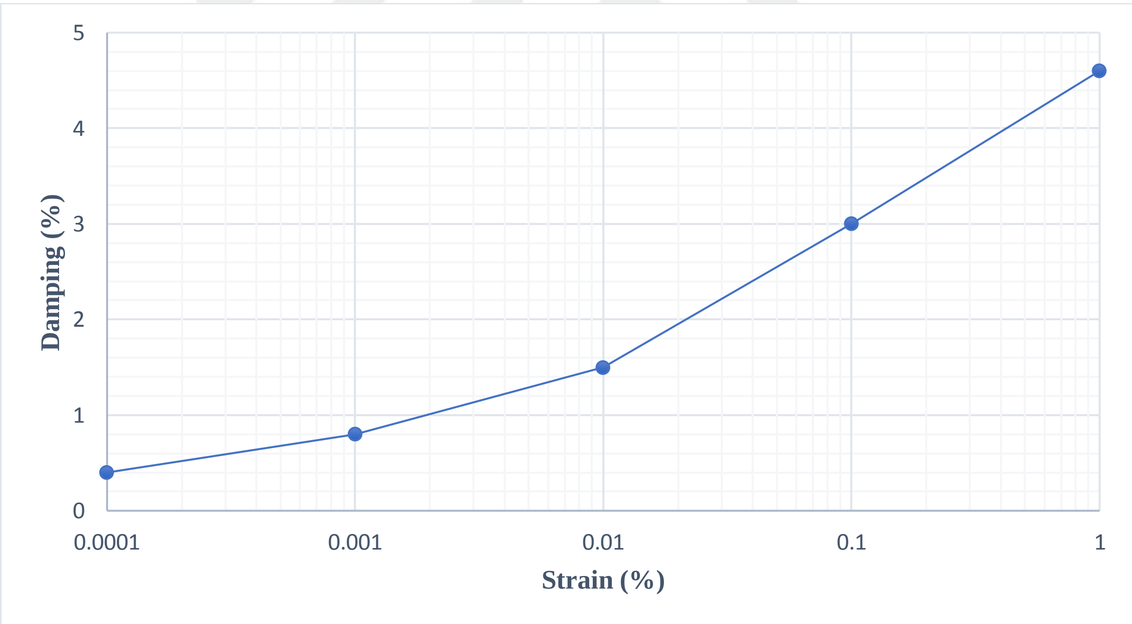

Figure 2.5. Damping Ratio Curve of Idriss for Rock Material

Moreover, at least seven earthquake acceleration records (due to TEC-2007) required for the continuation of SHAKE91 analyses were selected based on shear wave velocity to a depth of 30 meters, fault type, rupture distance, earthquake moment magnitude, and peak ground acceleration. In addition, due to the data limitations of the SHAKE91 program, these acceleration records have been filtered by using SeismoSignal (Seismosoft, 2016). Also, moment magnitude was chosen 7.0 due to earthquake events in Turkey and damping ratio was given 5% as default.

On the other hand, earthquake shaking travels through the ground, the waves lose energy, so high frequency waves lose energy more quickly than low frequency waves. The further you are from an earthquake the more the low frequency shaking dominates what you feel; therefore, in this study, an earthquake was used more than one education building due to location of seismic station and, as a result, different PGA values appeared for each seismic station.

Also, the earthquakes were selected in the following order when the tables are organized:

- Moment magnitude (M_w) was given 7.0 due to earthquake events in Turkey, so moment magnitude of selected earthquake records was about 7.0
- Peak ground accelerations (PGA) were selected as different from each other due to effect at response spectra.
- Rupture distance (R_{rup}) is relevant with directly fault distance of education building.
- Shear wave velocity to a depth of 30 meters (V_{s30}) was selected from PEER ground motion database with effect of properties of characterized soil profiles of each education buildings.
- When selecting the type of fault, fault types in Turkey's geography were considered.

Table 2.2. Information of Seven Earthquakes to Education Building-A

EDUCATION BUILDING-A					
EQ Name	**Magnitude (M_w)**	**PGA (g)**	**R_{rup} (km)**	**V_{S30}(m/s)**	**Fault Type**
Kobe	6.90	*0.251g*	*21.35*	*256*	*Strike Slip*
Northridge-01	6.69	*0.280g*	*20.81*	*255*	*Reverse*
Superstition Hills-02	6.54	*0.190g*	*27*	*206*	*Strike Slip*
Loma Prieta	6.93	*0,217g*	*14.34*	*222*	*Reverse Oblique*
Chuetsu-oki	*7.00*	*0,445g*	*10.97*	*201*	*Reverse*
Düzce	*7.14*	*0.806g*	*12.04*	*293*	*Strike Slip*
Imperial Valley-06	6.53	*0.187g*	*15.3*	*260*	*Strike Slip*

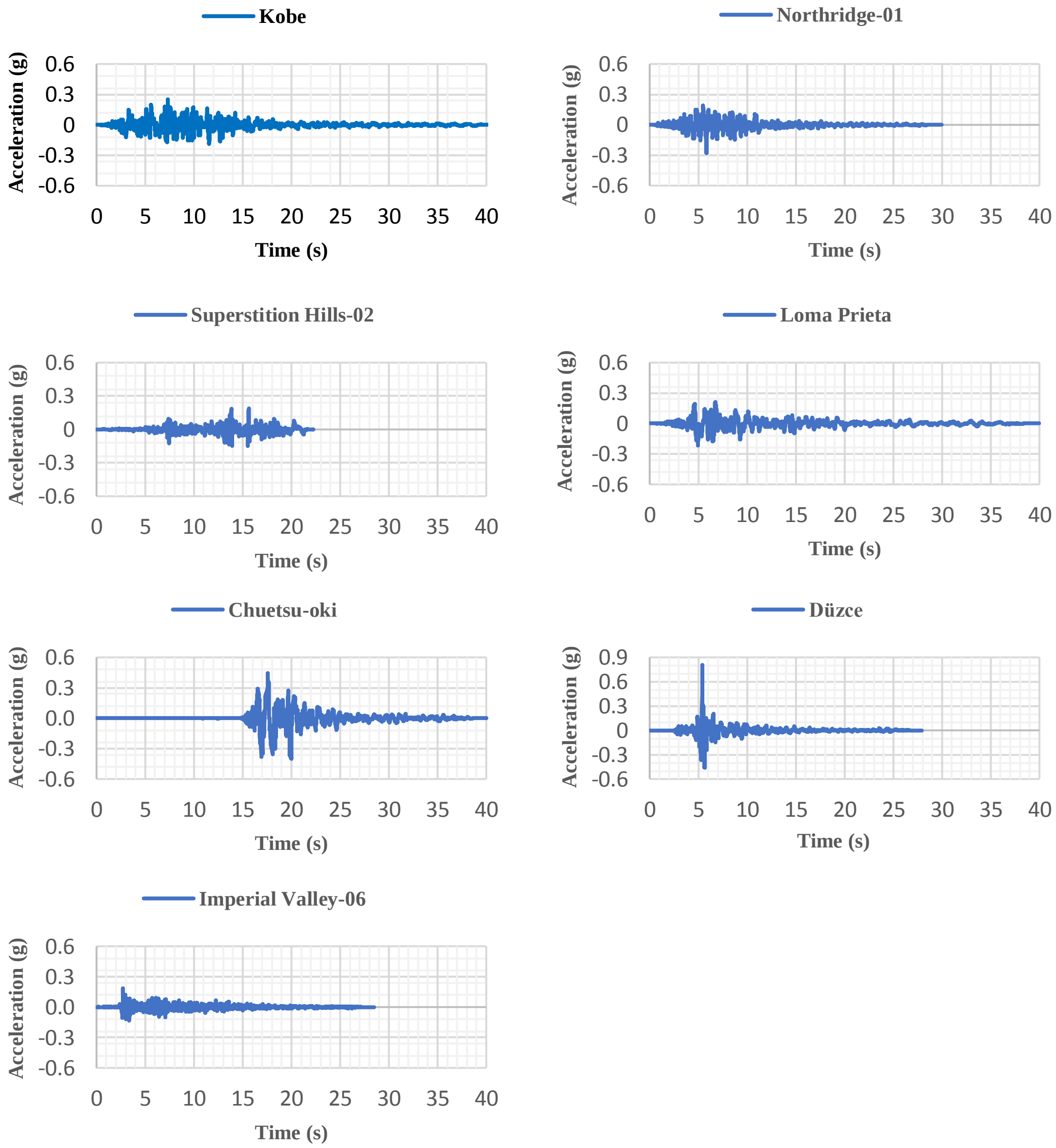

Figure 2.6. Acceleration-Time Histories Used for Education Building-A

Table 2.3. Information of Seven Earthquakes to Education Building-B

EDUCATION BUILDING-B					
EQ Name	**Magnitude (M_w)**	**PGA (g)**	**R_{rup} (km)**	**Vs_{30}(m/s)**	**Fault Type**
Imperial Valley-06	6.53	*0.168g*	*15.19*	*471.53*	*Strike Slip*
Düzce	7.14	*0.131g*	*11.46*	*481.00*	*Strike Slip*
Cape Mendocino	7.01	*0.117g*	*19.95*	*457.06*	*Reverse*
Northridge-01	6.69	*0.568g*	*20.72*	*450.28*	*Reverse*
M. Yugoslavia	7.10	*0.367g*	*6.98*	*462.23*	*Reverse*
Tabas	7.35	*0.324g*	*13.94*	*471.53*	*Reverse*
Loma Prieta	6.93	*0.449g*	*10.72*	*476.54*	*Reverse Oblique*

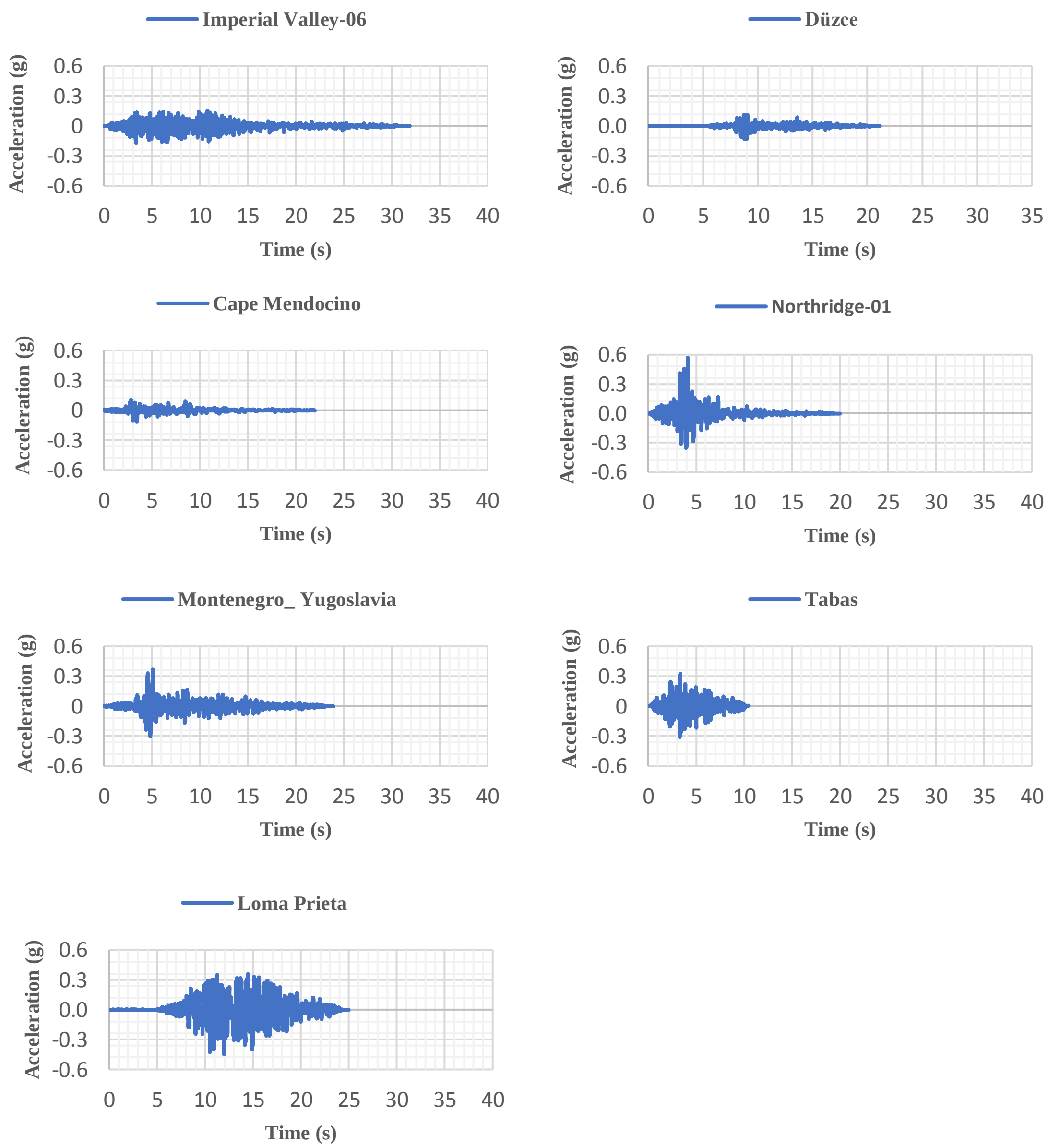

Figure 2.7. Acceleration-Time Histories Used for Education Building-B

Table 2.4. Information of Seven Earthquakes to Education Building-C

EDUCATION BUILDING-C					
EQ Name	**Magnitude (M_w)**	**PGA (g)**	**R_{rup} (km)**	**Vs_{30}(m/s)**	**Fault Type**
Cape Mendocino	*7.01*	*0.229g*	*25.91*	*515.65*	*Reverse*
Friuli Italy-01	*6.50*	*0.357g*	*15.82*	*505.23*	*Reverse*
Imperial Valley-06	*6.53*	*0.168g*	*15.19*	*471.53*	*Strike Slip*
Kobe	*6.90*	*0.483g*	*7.08*	*609.00*	*Strike Slip*
M. Yugoslavia	*7.10*	*0.464g*	*8.01*	*543.26*	*Reverse*
Nahanni Canada	*6.76*	*1.108g*	*9.6*	*605.04*	*Reverse*
Tabas	*7.35*	*0.324g*	*13.94*	*471.53*	*Reverse*

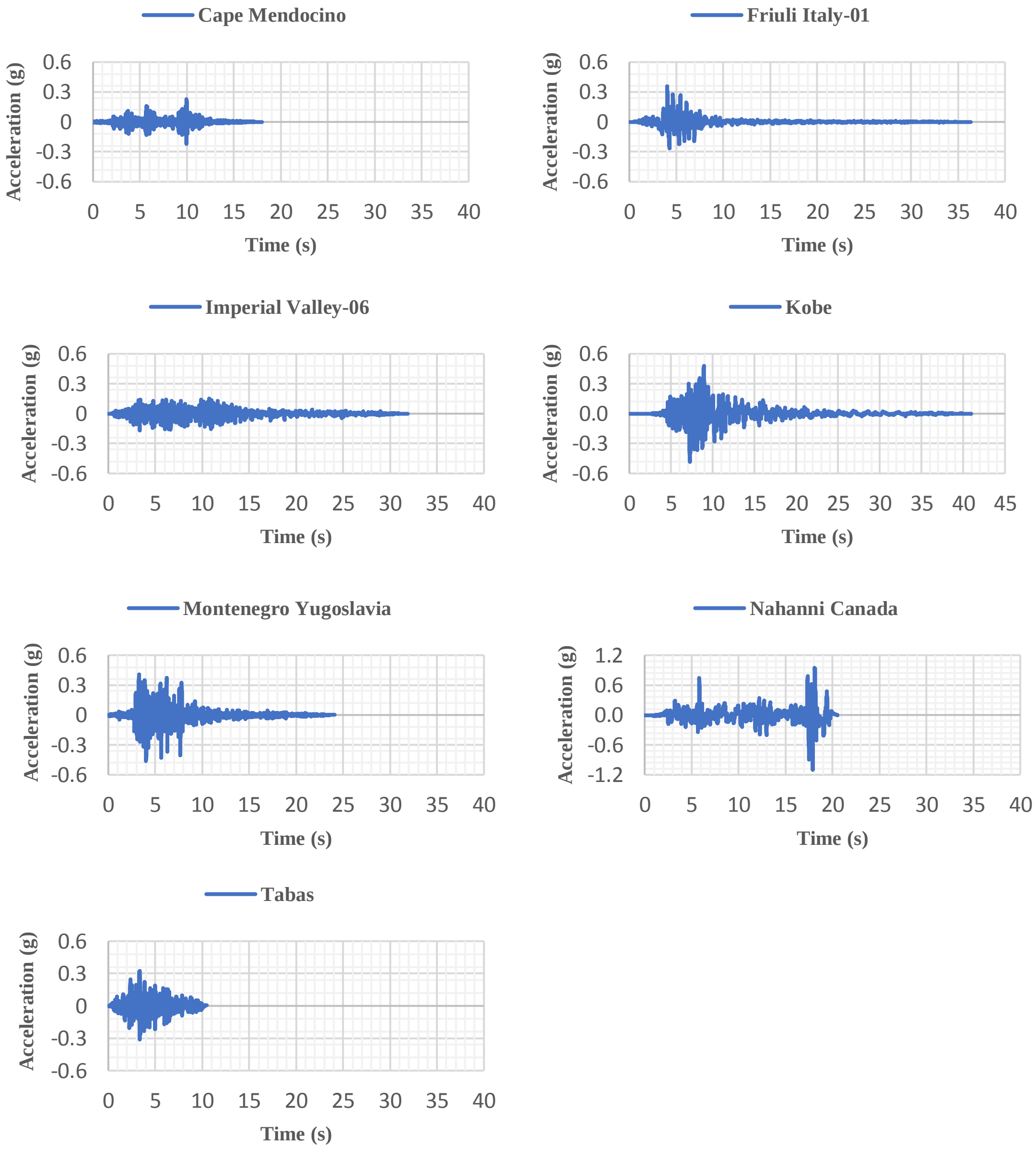

Figure 2.8. Acceleration-Time Histories Used for Education Building-C

The acceleration values in the top and bottom outcropping layers were obtained from Shake91 analysis. Besides, acceleration versus period information for the top and bottom outcropping layers was obtained with SeismoSignal help to get site specific spectra.

In other words, earthquakes spread from the bedrock to the surface through the overlying soil accumulation which behave as a filter and modify the ground motion characteristics. The alteration of the seismic waves with regards to amplitude, duration and frequency content at any depth can be evaluated through a ground response analysis. Due to its filter effect, the soil accumulation modifies the seismic waves by amplifying the signal at some specific frequencies and damping some others.

Also, ground response analysis of a soil accumulation can be considered as a preliminary study for the dynamic analysis of a structure because its seismic response is affected by the geological and geotechnical properties of the supporting soil layers.

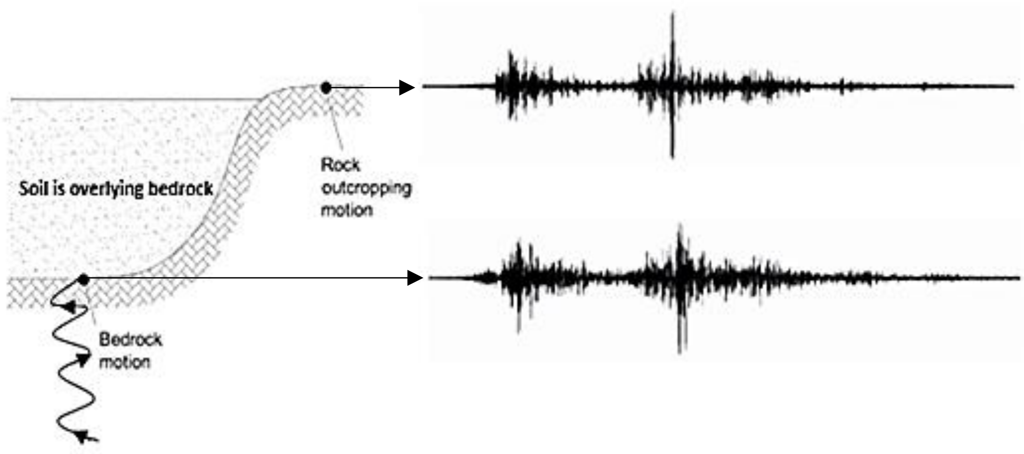

Figure 2.9. Outcropping Motion from Bottom to Top Outcropping Layers

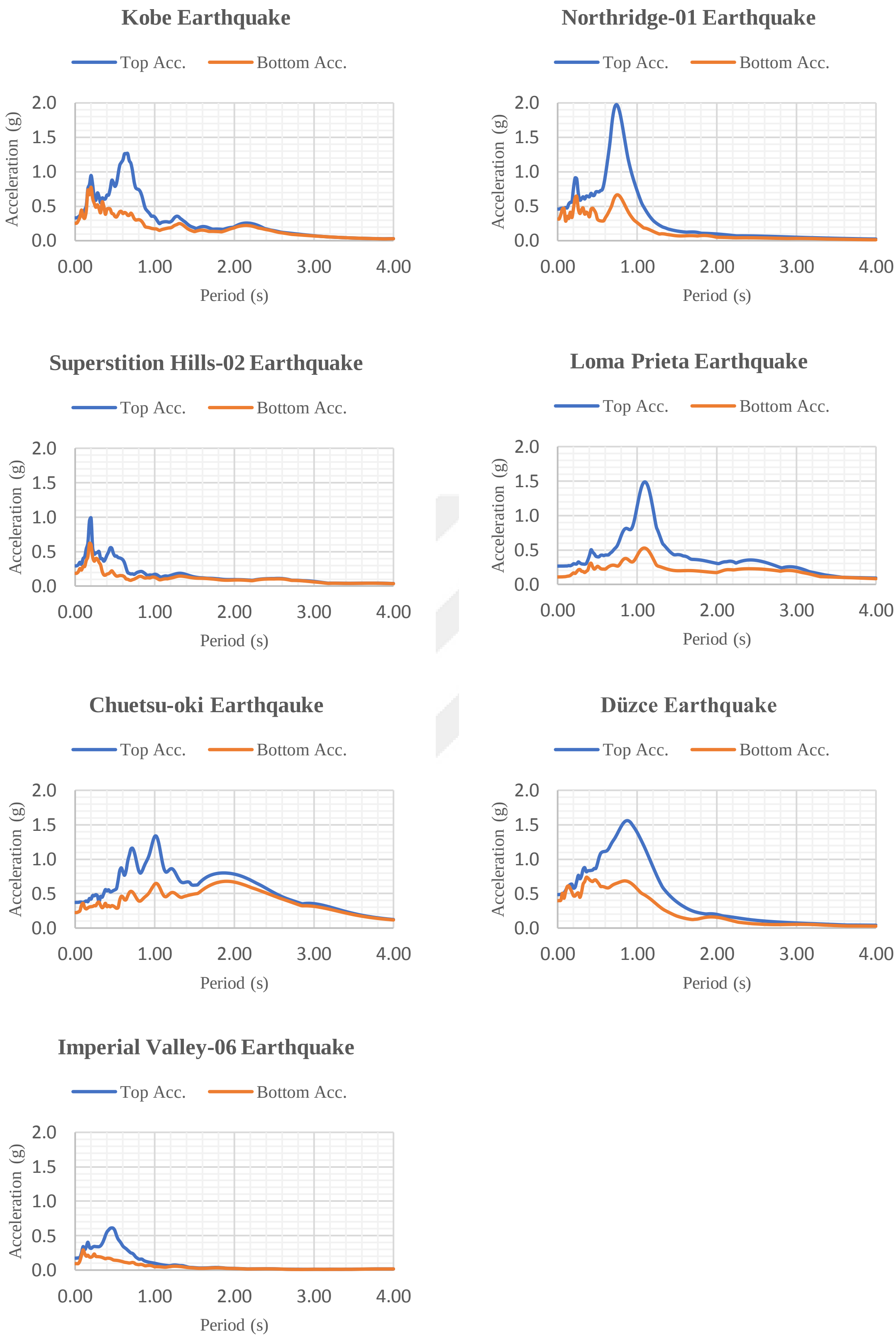

Figure 2.10. Acceleration Values at Top and Bottom Outcropping Layers for Education Building-A

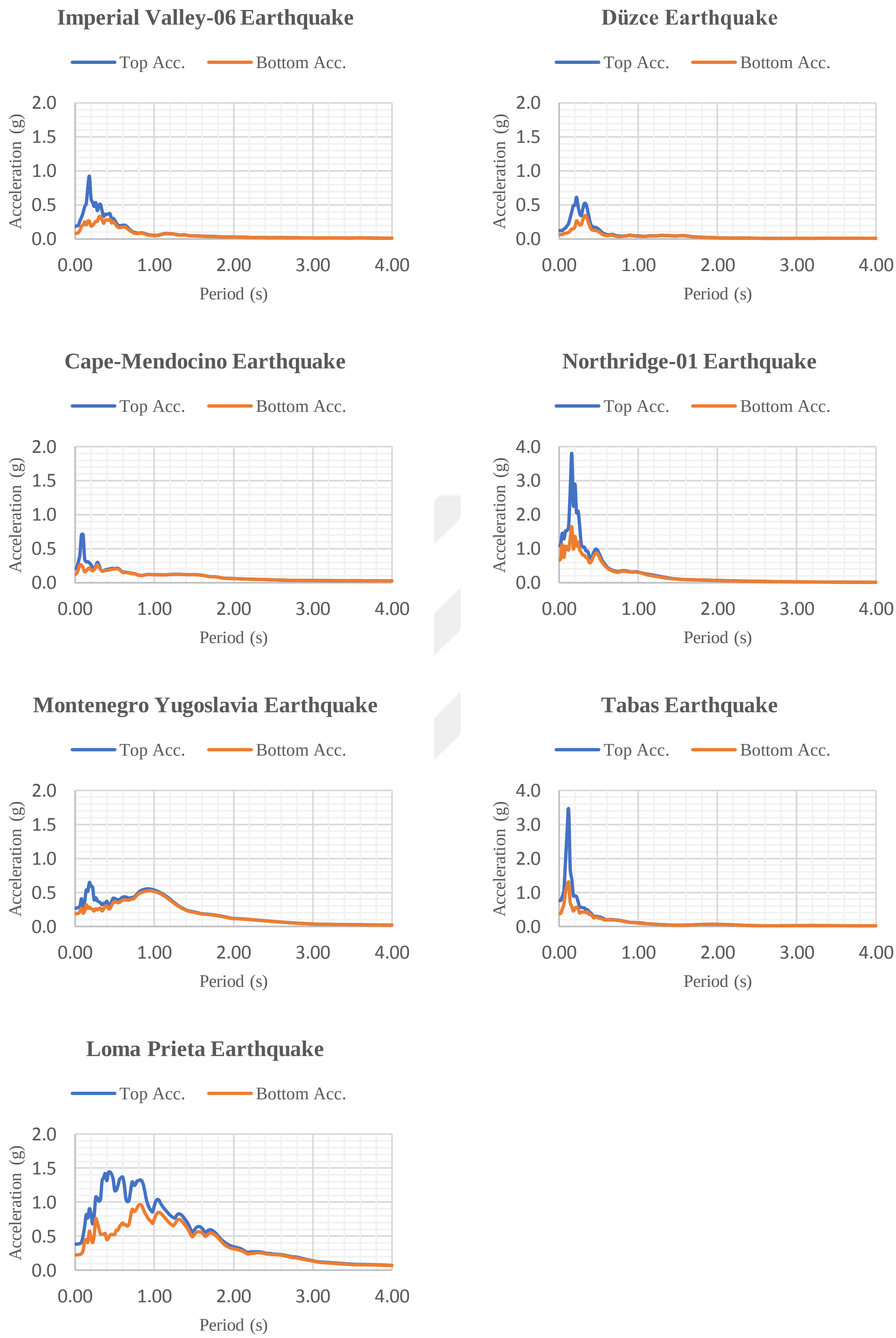

Figure 2.11. Acceleration Values at Top and Bottom Outcropping Layers for Education Building-B

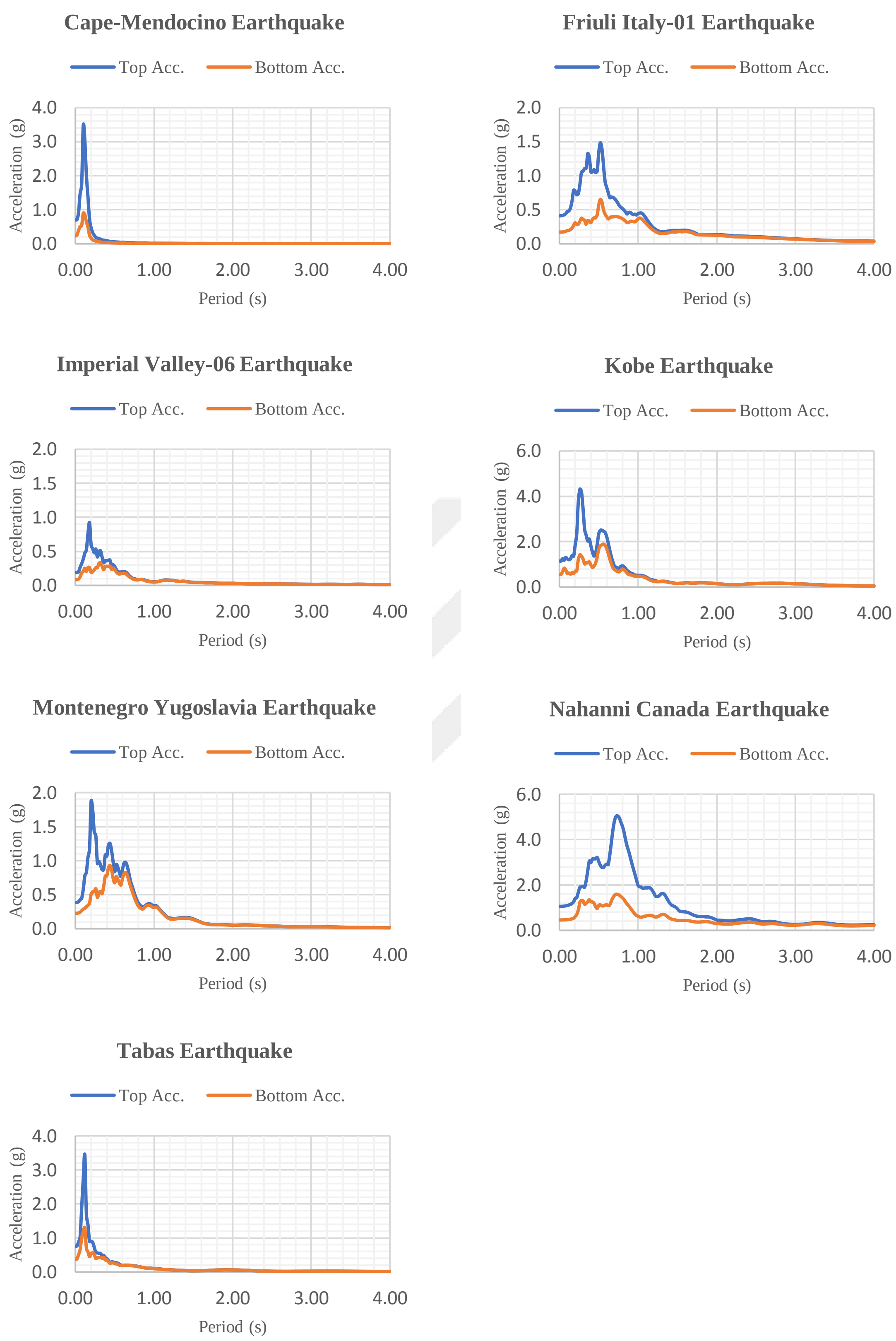

Figure 2.12. Acceleration Values at Top and Bottom Outcropping Layers for Education Building-C

Next, when obtaining the acceleration values in the top and bottom outcropping layers, amplification values were used for it because the main aim was comparing the effects of site-specific design spectra with that of the TEC design spectrum, so the following amplification formula was used when the response spectrum was obtained to each earthquake.

A_t = *Acceleration value of top outcropping layer at t seconds*

B_t = *Acceleration value of bottom outcropping layer at t seconds*

A_0 = *Acceleration value of top outcropping layer at 0 seconds*

B_0 = *Acceleration value of bottom outcropping layer at 0 seconds*

a_t = *Amplified acceleration value at t seconds*

$$\frac{A_t/B_t}{A_0/B_0} = a_t\ (t \geq 0)$$

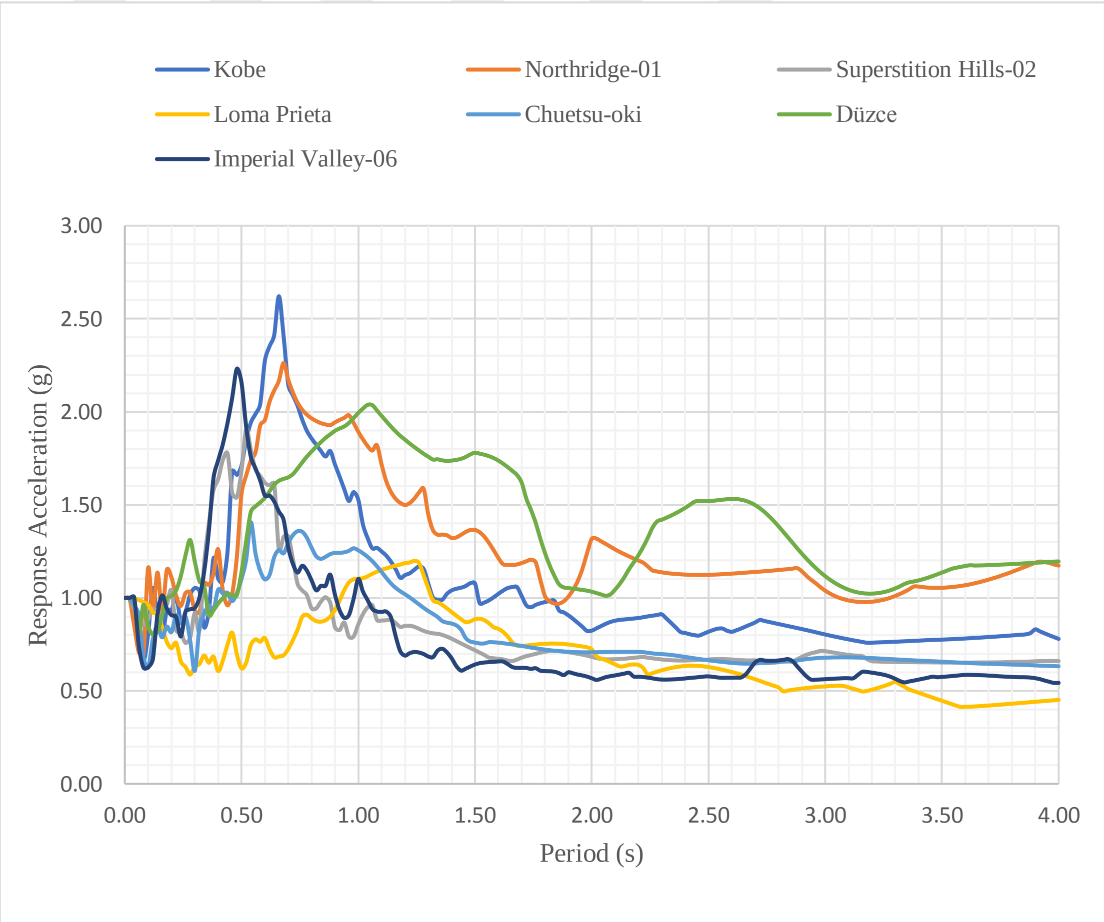

Figure 2.13. Response Spectra Used for Education Building-A

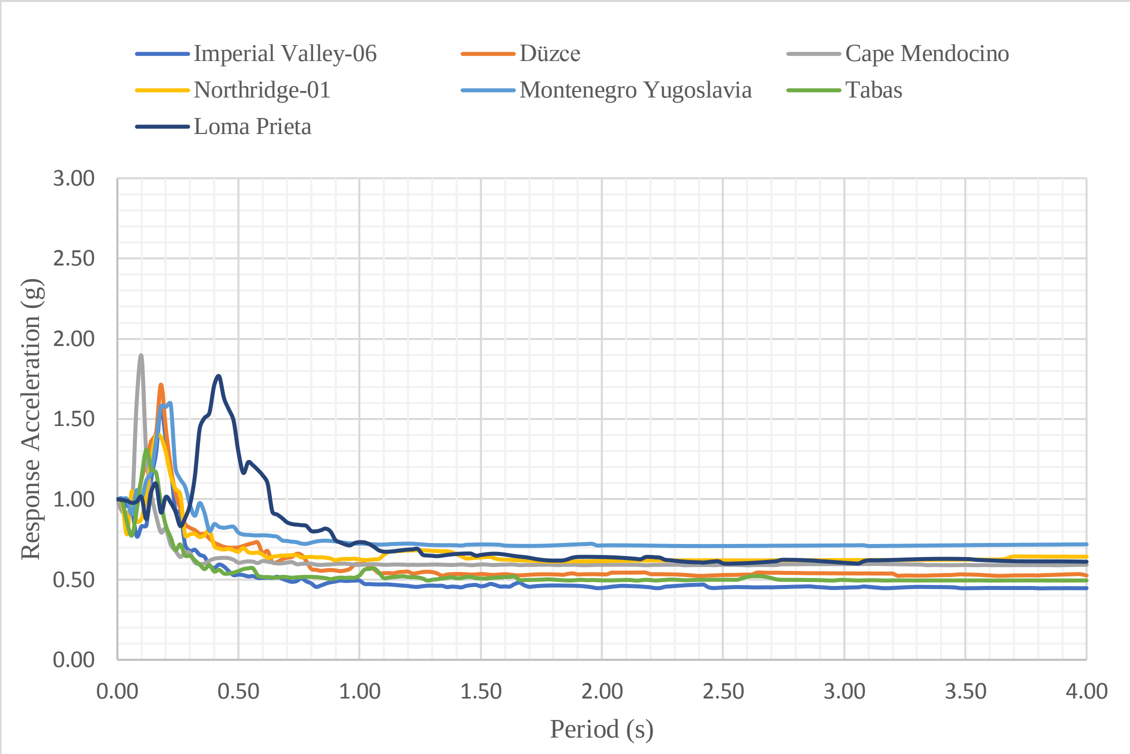

Figure 2.14. Response Spectra Used for Education Building-B

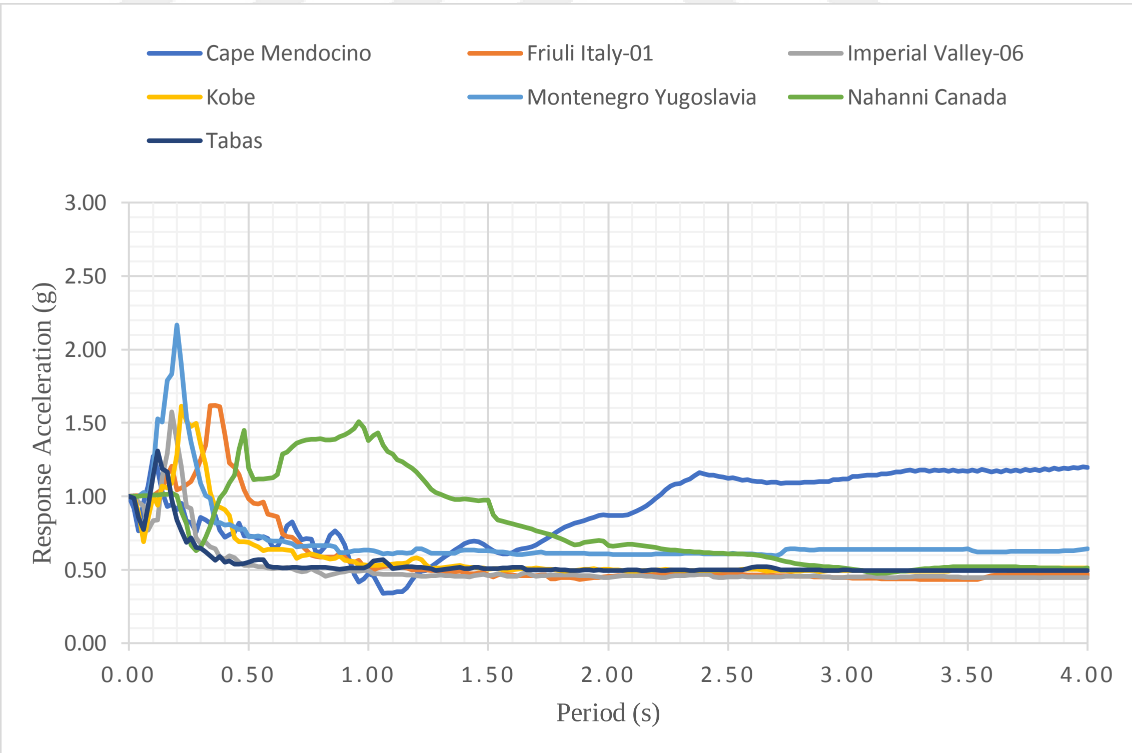

Figure 2.15. Response Spectra Used for Education Building-C

The response spectra were started at 1.00g due to amplification and their average value gave return periods of 50 years (Mean) to make comparison between site specific and Turkish earthquake code (TEC) design spectra.

On the other hand, education buildings A and B are at 1st seismic zone and their local soil class is Z3, so T_A=0.15s and T_B=0.6s. Education building C is at 1st seismic zone and its local soil class is Z4, so T_A=0.2s and T_B=0.9s according to TEC.

Therefore, the following spectrum coefficient *S(T)* formulas were used from TEC to obtain the design spectrum.

S(T) = Spectrum coefficient

T = Natural period of building

T_A , T_B = Spectrum Characteristic Periods

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

$$S(T) = 2.5 \qquad (T_A < T \le T_B)$$

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

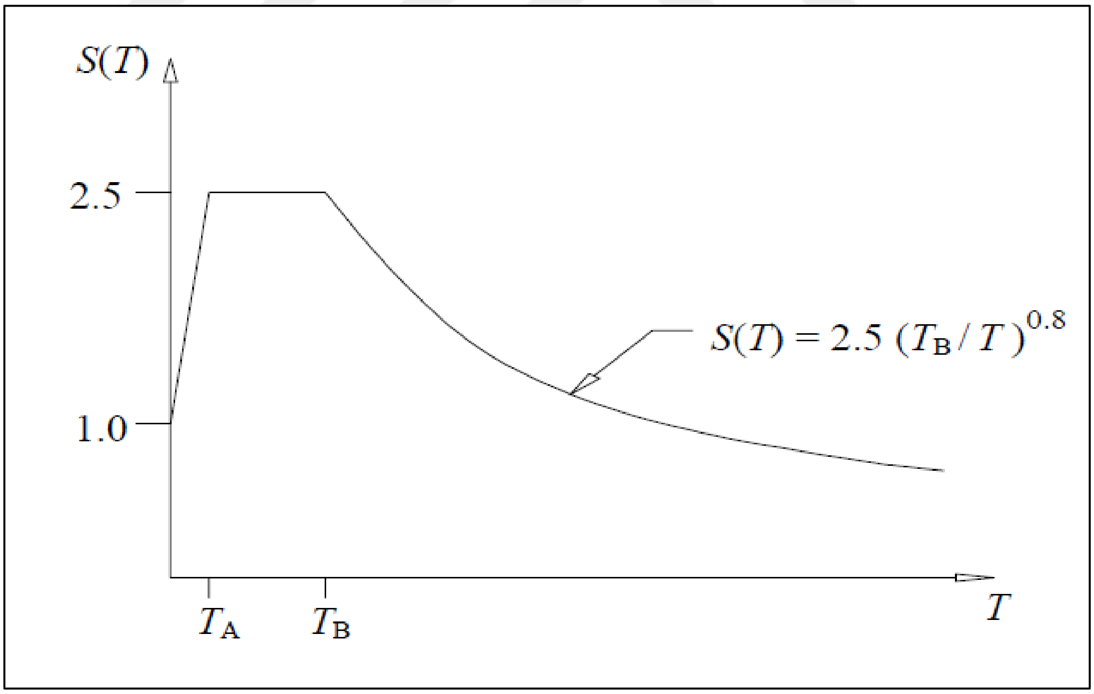

Figure 2.16. TEC Design Spectrum (TEC, 2007)

Also, the following spectrum coefficient *S(T)* formula of 50 years (Mean) return period were used for education buildings when the design spectra were obtained from each site-specific response spectra.

- *50 Years (Mean) Return Period used for education building A: T_A=0.45 T_B=0.9*

$$S(T) = 1 + 0.6\frac{T}{T_A} \qquad (0 \le T \le T_A)$$

$$S(T) = 1.6 \qquad (T_A < T \le T_B)$$

$$S(T) = 1.615\left(\frac{T_B}{T}\right)^{0.46} \qquad (T_B < T)$$

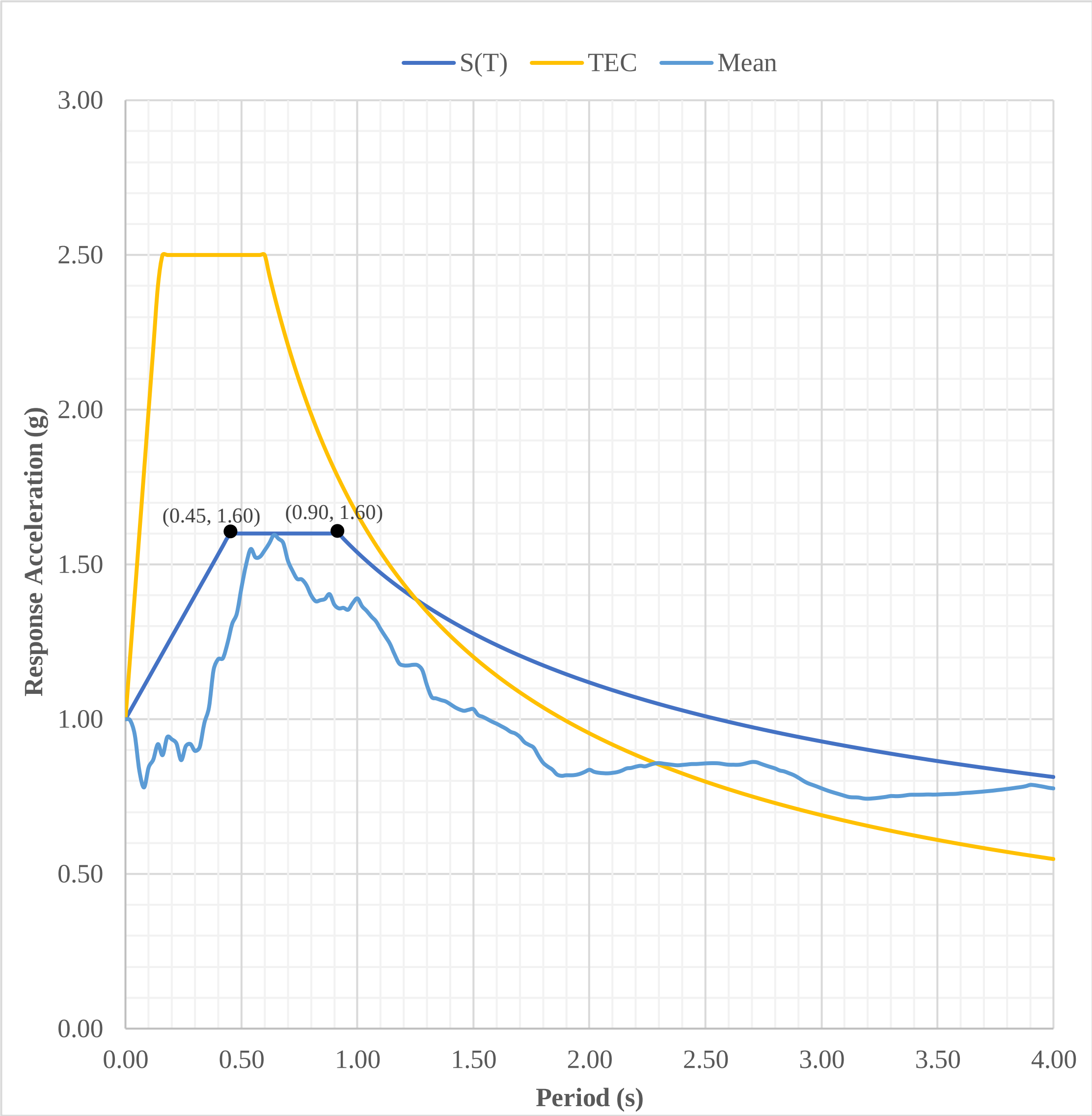

Figure 2.17. Earthquake Design Spectra of Education Building-A

- *50 Years (Mean) Return Period used for education building B:* T_A=0.12 T_B=0.25

$$S(T) = 1 + 0.27\frac{T}{T_A} \qquad (0 \leq T \leq T_A)$$

$$S(T) = 1.28 \qquad (T_A < T \leq T_B)$$

$$S(T) = 1.29\left(\frac{T_B}{T}\right)^{0.28} \qquad (T_B < T)$$

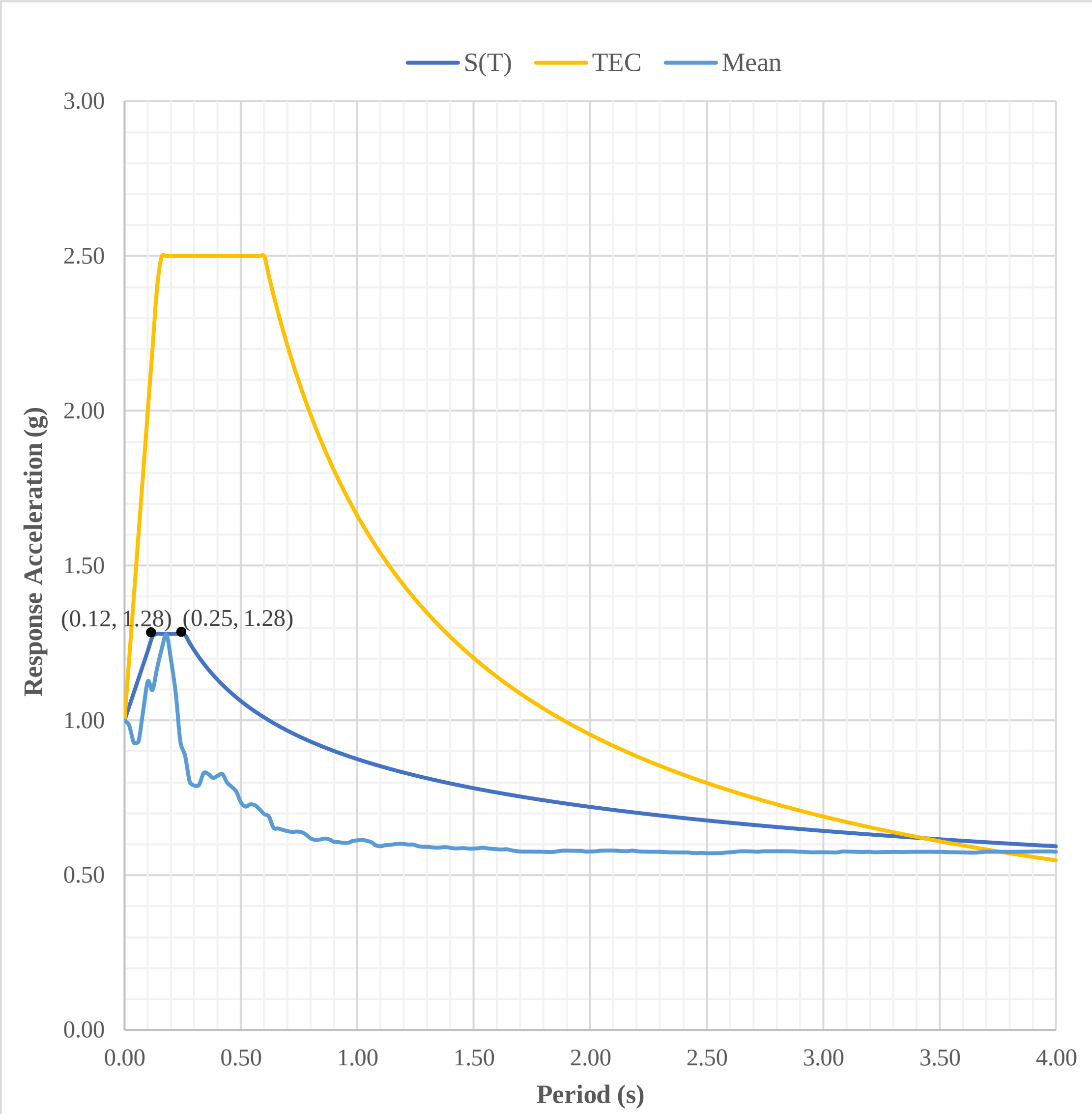

Figure 2.18. Earthquake Design Spectra of Education Building-B

- *50 Years (Mean) Return Period used for education building C:* $T_A=0.13$ $T_B=0.26$

$$S(T) = 1 + 0.25\frac{T}{T_A} \qquad (0 \le T \le T_A)$$

$$S(T) = 1.25 \qquad (T_A < T \le T_B)$$

$$S(T) = 1.26\left(\frac{T_B}{T}\right)^{0.25} \qquad (T_B < T)$$

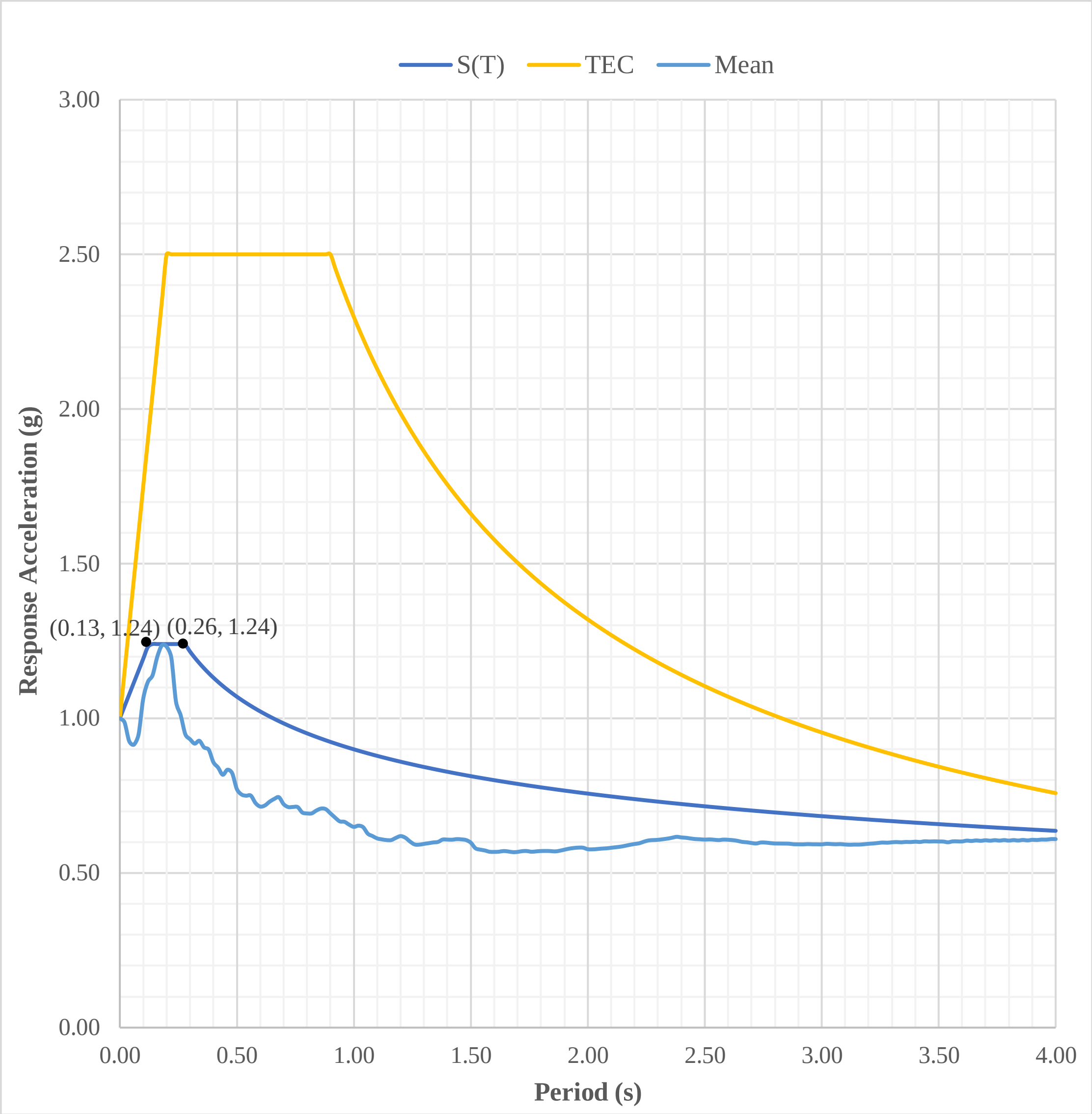

Figure 2.19. Earthquake Design Spectra of Education Building-C

2.2. Equivalent Seismic Load Method

2.2.1. Application limits of equivalent seismic load method

Within the aim of this study, buildings to which equivalent seismic load method can be applied are summarized below with respect to TEC-2007.

- If seismic zone of building is 1 or 2
- Total height of building ($H_N \leq 25$m)
- Buildings in which torsional irregularity coefficient (η_{bi}) satisfies the following condition:

  $\eta_{bi} \leq 2.0$ at every storey

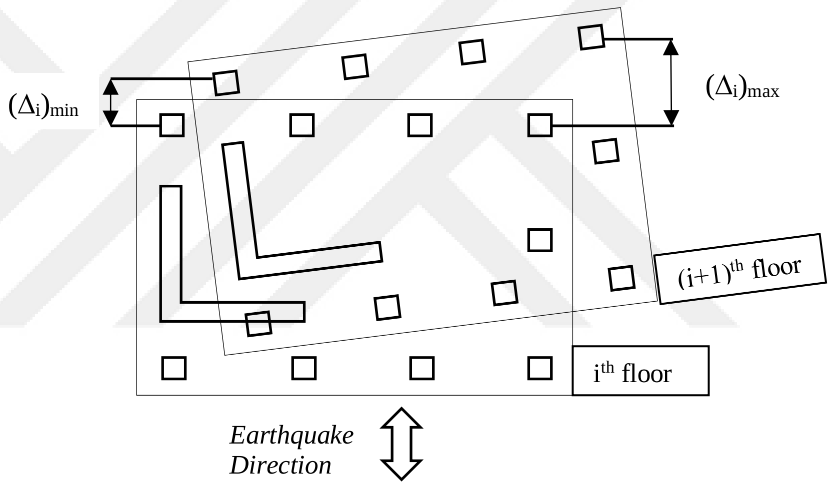

Figure 2.20. If the floors work as rigid diaphragms in its own plane (TEC, 2007)

As seen above, torsional irregularity factor can be defined as two orthogonal earthquake directions as the ratio of the maximum relative storey drift at any storey to the average relative storey drift at the same storey in the same direction. Then we can obtain this factor as written below :

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

$$\eta_{bi} = (\Delta_i)_{max} \, / \, (\Delta_i)_{avr} \qquad (2.1)$$

Also, in the case where torsional irregularity defined above exists at any i^{th} storey such that the condition $1.2 < \eta_{bi} < 2.0$ is satisfied, ± 5% additional eccentricity applied to this floor and should be amplified by multiplying with coefficient D_i given by equation for both earthquake directions.

$$D_i = \left(\frac{\eta_{bi}}{1.2}\right)^2 \quad (2.2)$$

Accordingly, when necessary controls were made for three education buildings, the following values were obtained with respect to design spectra of TEC 2007 and site-specific spectra of education buildings.

Firstly, education building-A was examined with its total height (12.9m < 25m) and torsional irregularity factors of each floor.

Table 2.5. Torsional Irregularity Factors of Education Building-A

Load Case DX+	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00285	0.00247	1.155 < 2.0	-
	2	0.00350	0.00316	1.107 < 2.0	-
	3	0.00345	0.00316	1.094 < 2.0	-
	4	0.00286	0.00267	1.074 < 2.0	-
Site Specific Spectra	1	0.00658	0.00569	1.155 < 2.0	-
	2	0.00807	0.00729	1.107 < 2.0	-
	3	0.00797	0.00728	1.094 < 2.0	-
	4	0.00660	0.00615	1.074 < 2.0	-

Load Case DX-	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00264	0.00232	1.139 < 2.0	-
	2	0.00349	0.00313	1.115 < 2.0	-
	3	0.00341	0.00311	1.099 < 2.0	-
	4	0.00285	0.00259	1.099 < 2.0	-
Site Specific Spectra	1	0.00610	0.00598	1.139 < 2.0	-
	2	0.00805	0.00717	1.115 < 2.0	-
	3	0.00788	0.00722	1.099 < 2.0	-
	4	0.00657	0.00535	1.099 < 2.0	-

Load Case DY+	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00627	0.00468	1.339 < 2.0	6.2
	2	0.00800	0.00617	1.296 < 2.0	5.8
	3	0.00689	0.00572	1.204 < 2.0	5.1
	4	0.00500	0.00451	1.109 < 2.0	-
Site Specific Spectra	1	0.01453	0.01085	1.339 < 2.0	6.2
	2	0.01854	0.01430	1.296 < 2.0	5.8
	3	0.01597	0.01326	1.204 < 2.0	5.1
	4	0.01158	0.01045	1.109 < 2.0	-

Load Case DY-	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00969	0.00714	1.358 < 2.0	6.4
	2	0.01213	0.00932	1.302 < 2.0	5.9
	3	0.01023	0.00827	1.237 < 2.0	5.3
	4	0.00723	0.00628	1.151 < 2.0	-
Site Specific Spectra	1	0.02247	0.01655	1.358 < 2.0	6.4
	2	0.02811	0.02159	1.302 < 2.0	5.9
	3	0.02371	0.01917	1.237 < 2.0	5.3
	4	0.01676	0.01456	1.151 < 2.0	-

Secondly, education building-B was examined with its total height (10.35m < 25m) and torsional irregularity factors of each floor.

Table 2.6. Torsional Irregularity Factors of Education Building-B

Load Case DX+	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00319	0.00264	1.071 < 2.0	-
	2	0.00408	0.00381	1.072 < 2.0	-
	3	0.00283	0.00298	1.070 < 2.0	-
Site Specific Spectra	1	0.00618	0.00577	1.071 < 2.0	-
	2	0.00789	0.00736	1.072 < 2.0	-
	3	0.00547	0.00511	1.070 < 2.0	-
Load Case DX-	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00327	0.00299	1.094 < 2.0	-
	2	0.00415	0.00382	1.087 < 2.0	-
	3	0.00285	0.00265	1.078 < 2.0	-
Site Specific Spectra	1	0.00633	0.00579	1.094 < 2.0	-
	2	0.00802	0.00738	1.087 < 2.0	-
	3	0.00552	0.00512	1.078 < 2.0	-
Load Case DY+	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00747	0.00655	1.140 < 2.0	-
	2	0.00973	0.00861	1.130 < 2.0	-
	3	0.00670	0.00597	1.122 < 2.0	-
Site Specific Spectra	1	0.01289	0.01131	1.140 < 2.0	-
	2	0.01680	0.01486	1.130 < 2.0	-
	3	0.01157	0.01031	1.122 < 2.0	-
Load Case DY-	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00782	0.00659	1.188 < 2.0	-
	2	0.01018	0.00866	1.176 < 2.0	-
	3	0.00698	0.00601	1.162 < 2.0	-
Site Specific Spectra	1	0.01351	0.01137	1.188 < 2.0	-
	2	0.01758	0.01495	1.176 < 2.0	-
	3	0.01206	0.01037	1.162 < 2.0	-

Finally, education building-C was examined with its total height (13.8m < 25m) and torsional irregularity factors of each floor.

Table 2.7. Torsional Irregularity Factors of Education Building-C

Load Case DX+	Floor	$(\Delta_i)_{max}$ (m)	$(\Delta_i)_{avr}$ (m)	η_{bi}	Additional Eccentricity
TEC 2007	1	0.00070	0.00053	1.323 < 2.0	6.1
	2	0.00266	0.00245	1.086 < 2.0	-
	3	0.00304	0.00283	1.075 < 2.0	-
	4	0.00237	0.00216	1.100 < 2.0	-
Site Specific Spectra	1	0.00101	0.00082	1.244 < 2.0	5.4
	2	0.00523	0.00481	1.087 < 2.0	-
	3	0.00599	0.00557	1.075 < 2.0	-
	4	0.00468	0.00426	1.100 < 2.0	-
Load Case DX-	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00072	0.00053	1.343 < 2.0	6.3
	2	0.00248	0.00236	1.050 < 2.0	-
	3	0.00284	0.00275	1.030 < 2.0	-
	4	0.00228	0.00207	1.102 < 2.0	-
Site Specific Spectra	1	0.00104	0.00082	1.270 < 2.0	5.6
	2	0.00486	0.00462	1.051 < 2.0	-
	3	0.00559	0.00543	1.030 < 2.0	-
	4	0.00451	0.00409	1.102 < 2.0	-
Load Case DY+	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00084	0.00069	1.221 < 2.0	5.2
	2	0.00315	0.00257	1.226 < 2.0	5.2
	3	0.00458	0.00366	1.251 < 2.0	5.4
	4	0.00438	0.00341	1.286 < 2.0	5.7
Site Specific Spectra	1	0.00135	0.00113	1.198 < 2.0	-
	2	0.00600	0.00486	1.235 < 2.0	5.3
	3	0.00874	0.00699	1.252 < 2.0	5.4
	4	0.00838	0.00651	1.287 < 2.0	5.7
Load Case DY-	**Floor**	**$(\Delta_i)_{max}$ (m)**	**$(\Delta_i)_{avr}$ (m)**	**η_{bi}**	**Additional Eccentricity**
TEC 2007	1	0.00090	0.000689	1.308 < 2.0	5.9
	2	0.00287	0.00251	1.145 < 2.0	-
	3	0.00397	0.00360	1.102 < 2.0	-
	4	0.00376	0.00332	1.131 < 2.0	-
Site Specific Spectra	1	0.00147	0.00113	1.300 < 2.0	5.9
	2	0.00545	0.00475	1.146 < 2.0	-
	3	0.00755	0.00687	1.099 < 2.0	-
	4	0.00718	0.00635	1.130 < 2.0	-

As seen in tables, torsional irregularity factors were conforming with TEC 2007 condition ($\eta_{bi} \leq 2.0$) at every storey. Their total heights ($H_N \leq 25$m); so equivalent seismic load method was determined to be applicable to these three education buildings.

2.2.2. Determination of total equivalent seismic load

In the design approach based on force, earthquake loads obtained from design spectrum are reduced according to the ductility level and linear elastic analysis is performed. However, when the existing building evaluation is performed, load reduction coefficient (R_a) is accepted to be "1" and linear elastic analysis is performed accordingly. Namely, when the seismic performance evaluation is carried out, unreduced earthquake loads are applied to structural elements and the proportions of the capacities of the elements are compared with their limit values which are expressed as effect/capacity ratios in chapter 7.5.2 of TEC-2007

Equivalent seismic loads are determined in accordance with TEC-2007. In this context, the equivalent seismic load acting on the building, in other words, the base shear force "V_t" will be determined by the following equation.

$$V_t = \frac{W.A_o.I.S(T)}{R_a(T)} \geq 0.10.A_0.I.W \tag{2.3}$$

Within the scope of this equation, the education buildings examined are located in the first-degree earthquake zone, so effective ground acceleration coefficient "A_0" was taken as 0.4 and importance factor of building "I" was taken as 1 due to existing building. On the other hand, S(T) was calculated with site specific spectra at previous section. In addition, the seismic load reduction coefficient "$R_a(T)$" is taken as 1 because the base shear forces are considered in current building performance evaluation process. Otherwise, $R_a(T)$ will be calculated with the help of the following equations using the structural system behavior coefficient "R"

$$R_a(T) = 1.5 + (R - 1.5)\frac{T}{T_A} \qquad (0 \leq T \leq T_A)$$
$$R_a(T) = R \qquad (T_A < T) \tag{2.4}$$

Total seismic weight of building "W" in equation (2.3) will be calculated by the equation (2.5)

$$W = \sum_{i=1}^{N} w_i \tag{2.5}$$

In this equation, "N" is total number of stories and storey weights "w_i" calculated by equation (2.6)

$$w_i = g_i + nq_i \tag{2.6}$$

Live load participation factor "n" in equation (2.6) will be taken as 0.6 (school) according to TEC-2007.

Earthquake loads acting on each building storey of total equivalent seismic load are stated by equation (2.7)

$$V_t = \Delta F_N + \sum_{i=1}^{N} F_i \tag{2.7}$$

Additional equivalent seismic load "ΔF_n" acting at top (N^{th}) storey of building can be calculated with equation (2.8)

$$\Delta F_N = 0.0075.N.V_t \tag{2.8}$$

Except ΔF_n, total equivalent earthquake load is distributed to building stories with the following equation (2.9)

$$F_i = (V_t - \Delta \mathrm{F}_N)\frac{w_i H_i}{\sum_{j=1}^{N} w_j H_j} \tag{2.9}$$

The acceleration spectrum defined in TEC-2007 is based on the earthquake effect with a probability of exceeding 10% in 50 years, so acceleration spectrum of probability of exceeding 2% in 50 years will be taken as 1.5 times at building performance evaluation and equivalent seismic load calculation. On the other hand, in addition to the design spectrum included in TEC-2007, building performance evaluation and equivalent earthquake load calculations will be carried out using the site-specific design spectrum.

2.2.2.1. General characteristics of education buildings

In this study, there are three education buildings constructed conforming to TEC-1975 regulation. Their building geometries, material properties, earthquake parameters, and storey formwork plan are shown in the following table and figures. As seen in Figure 2.24. – Figure 2.26. education buildings A and C have shear walls in varying ratios.

Table 2.8. General Characteristics of Education Buildings

	Education Building- A	**Education Building- B**	**Education Building- C**
Number of Stories	4	3	4
Building Height (m)	12.90	10.35	13.80
Area of the Building (m^2)	37.25x17.20	29.80x14.80	38.70x17.70
Total Seismic Weight of Building (kN)	27630.90	11694.90	25568.80
Concrete Class	C12	C7	C8
Reinforcement Steel Class	S420	S220	S220
Local Site Class	Z3	Z3	Z4
Seismic Zone= 1, I= 1, R= 1, n= 0.6, A_0= 0.4			

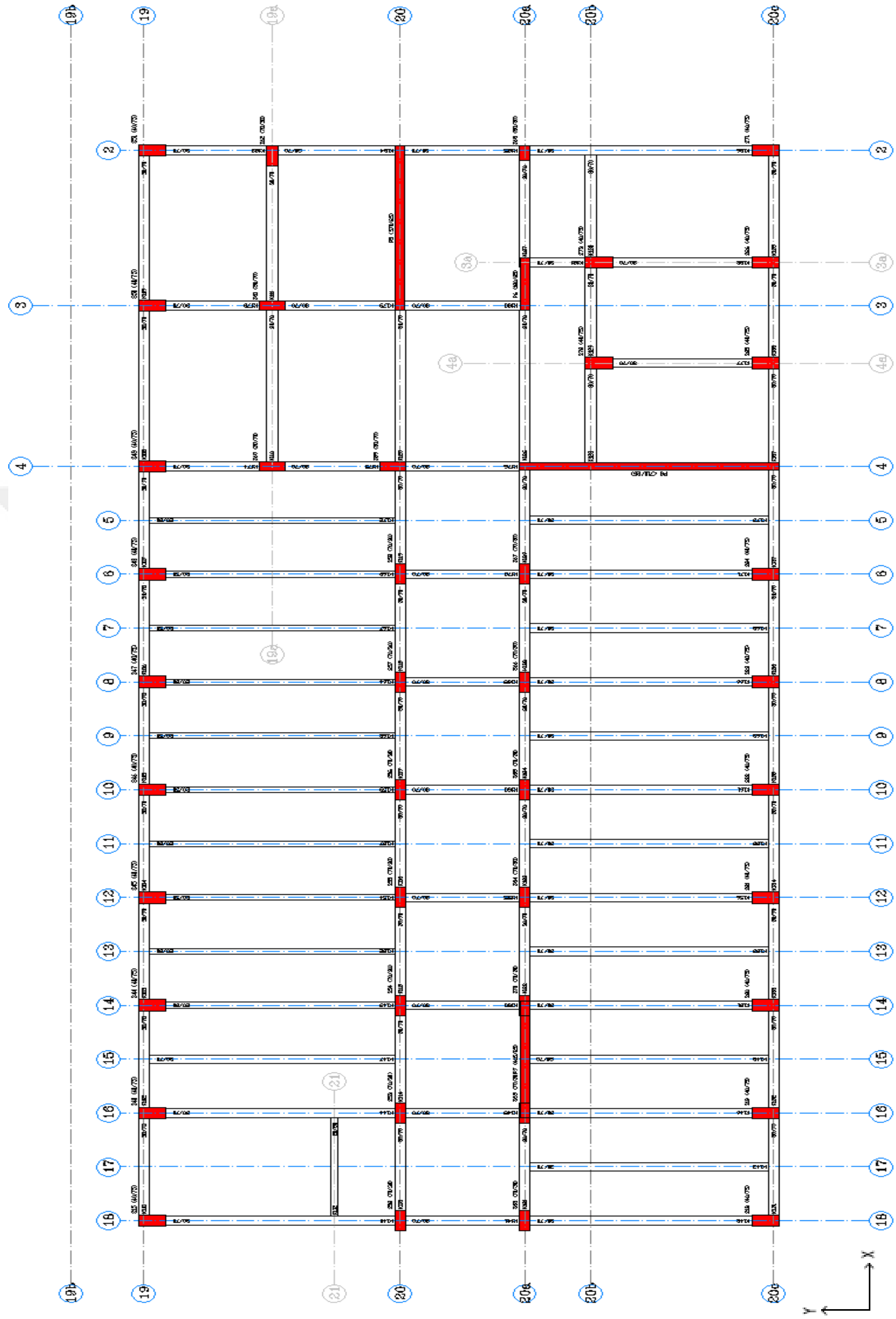

Figure 2.21. Storey Formwork Plan for Education Building-A

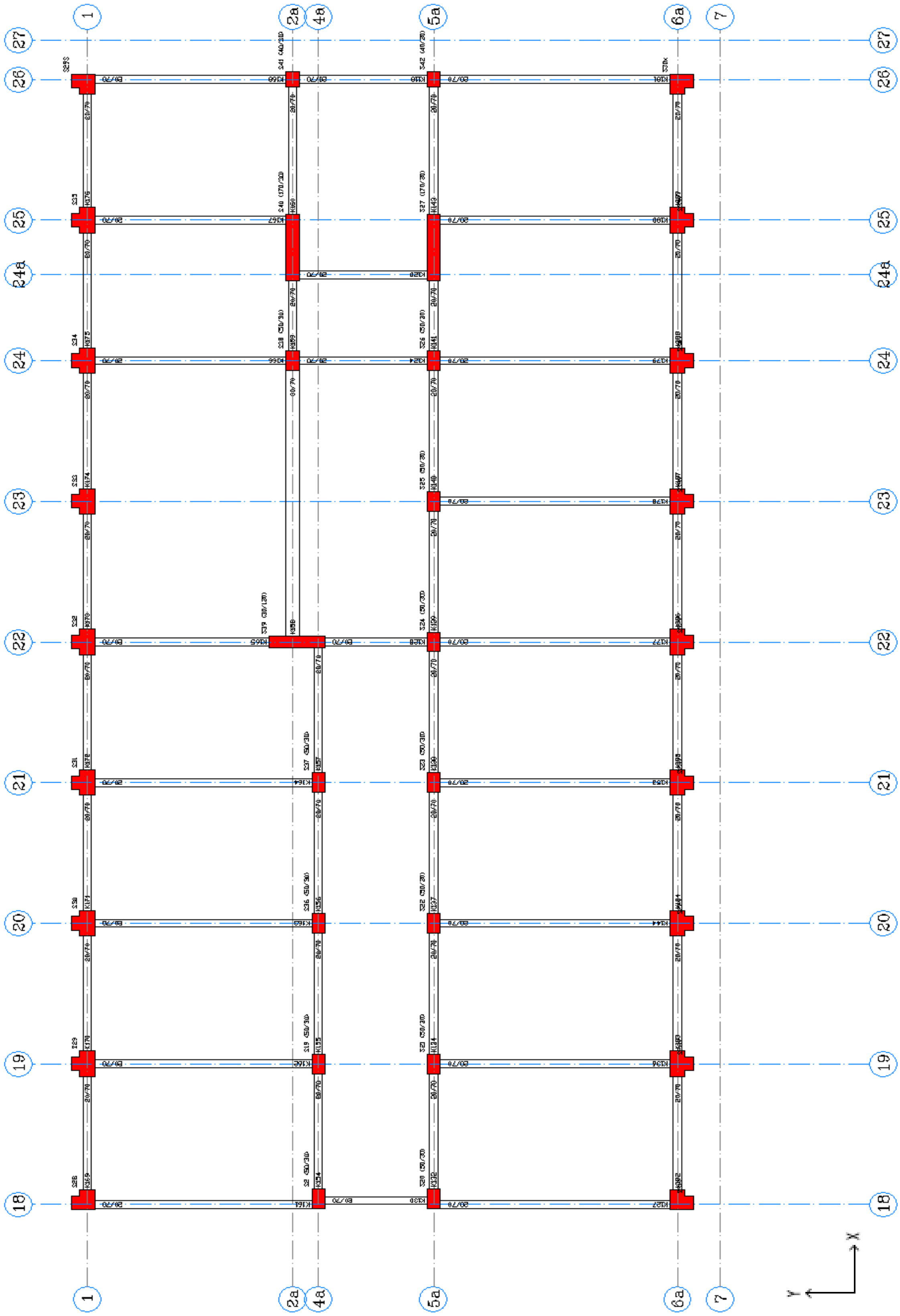

Figure 2.22. Storey Formwork Plan for Education Building-B

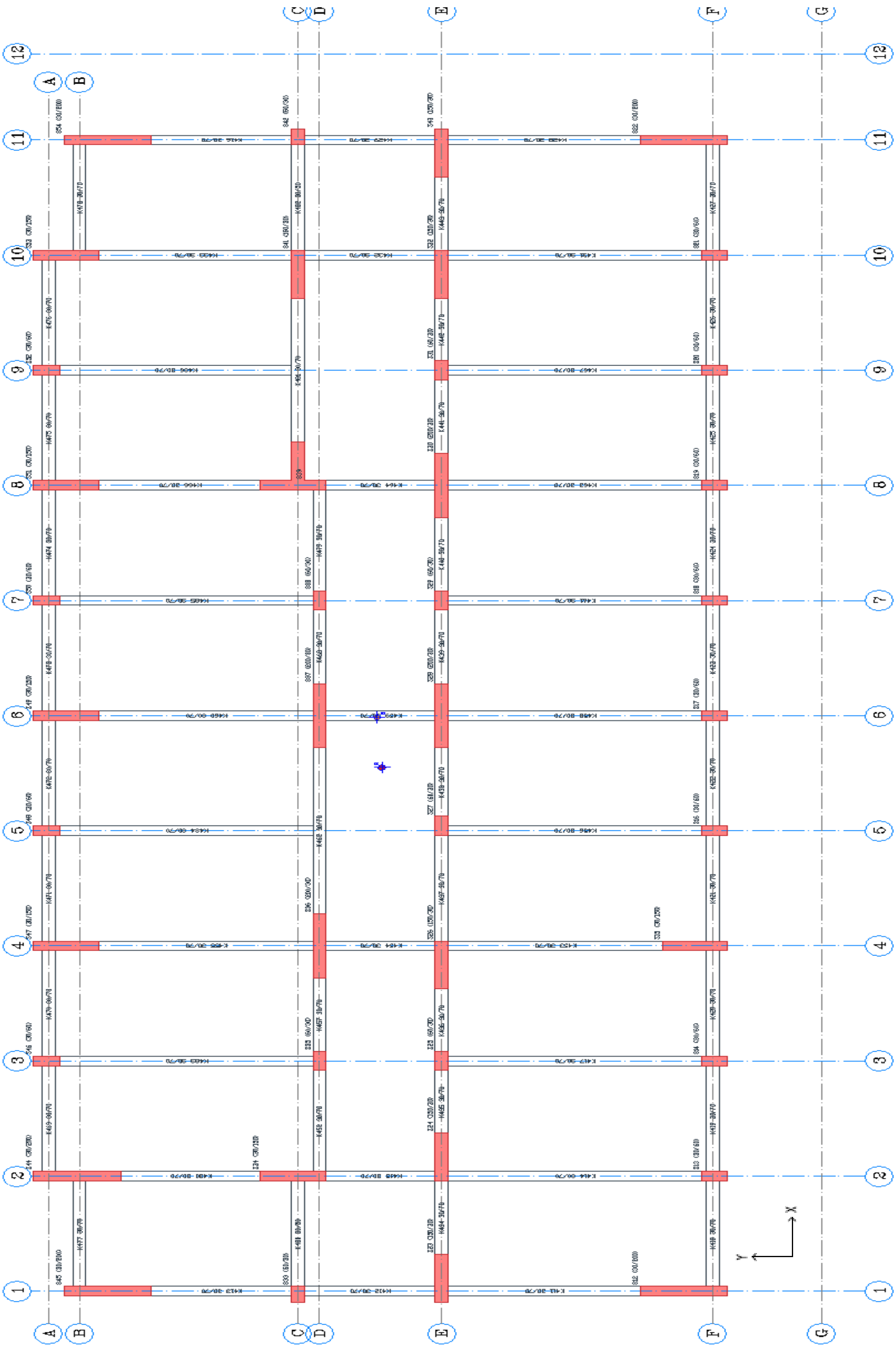

Figure 2.23. Storey Formwork Plan for Education Building-C

2.2.2.2. *Calculation of base shear forces*

Table 2.9. Base Shear Forces of Education Building-A with RU/LS (F=1.0)

TEC-2007 Design Spectrum				*Site-Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	7154.4	2982.1	2982.1	*1*	7154.4	1720.2	1803.6
2	7117.3	5680.9	5680.9	*2*	7117.3	3277.0	3276.5
3	7143.5	8425.1	8425.1	*3*	7143.5	4860.0	4859.3
4	6215.7	10542.8	10542.8	*4*	6215.7	6081.6	6080.7
Σ	27630.9	27630.9	27630.9	Σ	27630.9	15938.8	16020.1
[T_A=0.15, T_B=0.60]				*[T_A=0.45, T_B=0.90]*			
[Performance Status : RU and LS, F=1.0] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.3316, T_y=0.3371]							

Table 2.10. Base Shear Forces of Education Building-A with LS (F=1.5)

TEC-2007 Design Spectrum				*Site-Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	7154.4	4473.1	4473.1	*1*	7154.4	2580.1	2592.4
2	7117.3	8521.3	8521.3	*2*	7117.3	4915.1	4938.6
3	7143.5	12637.7	12637.7	*3*	7143.5	7289.4	7324.3
4	6215.7	15814.2	15814.2	*4*	6215.7	9121.6	9165.2
Σ	27630.9	41446.3	41446.3	Σ	27630.9	23906.1	24020.6
[T_A=0.15, T_B=0.60]				*[T_A=0.45, T_B=0.90]*			
[Performance Status : LS, F=1.5] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.3316, T_y=0.3371]							

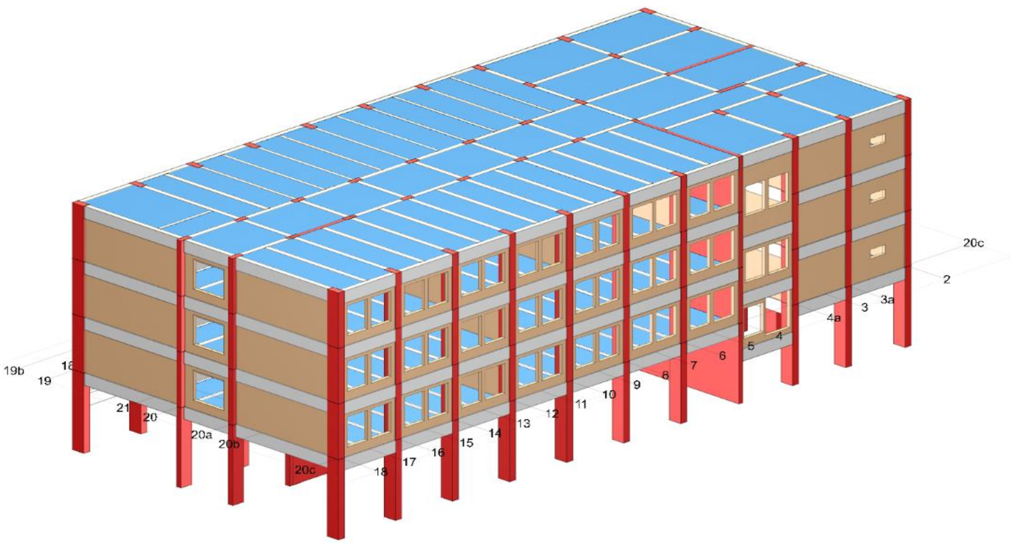

Figure 2.24. 3-D View of Education Building-A

Table 2.11. Base Shear Forces of Education Building-B with RU/LS (F=1.0)

TEC-2007 Design Spectrum				*Site Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	4123.2	2071.7	2071.7	*1*	4123.2	978.9	862.6
2	4086.8	4107.0	4107.0	*2*	4086.8	1940.6	1710.0
3	3484.9	5516.2	5516.2	*3*	3484.9	2606.5	2296.8
Σ	11694.9	11694.9	11694.9	Σ	11694.9	5526.0	4869.4
[T_A=0.15, T_B=0.60]				*[T_A=0.12, T_B=0.25]*			
[Performance Status : RU and LS, F=1.0] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.3165, T_y=0.4737]							

Table 2.12. Base Shear Forces of Education Building-B with LS (F=1.5)

TEC-2007 Design Spectrum				*Site Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	4123.2	3107.6	3107.6	*1*	4123.2	1468.4	1293.9
2	4086.8	6160.4	6160.4	*2*	4086.8	2910.9	2568.0
3	3484.9	8274.3	8274.3	*3*	3484.9	3909.7	3445.2
Σ	11694.9	17542.3	17542.3	Σ	11694.9	8289.0	7304.1
[T_A=0.15, T_B=0.60]				*[T_A=0.12, T_B=0.25]*			
[Performance Status : LS, F=1.5] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.3165, T_y=0.4737]							

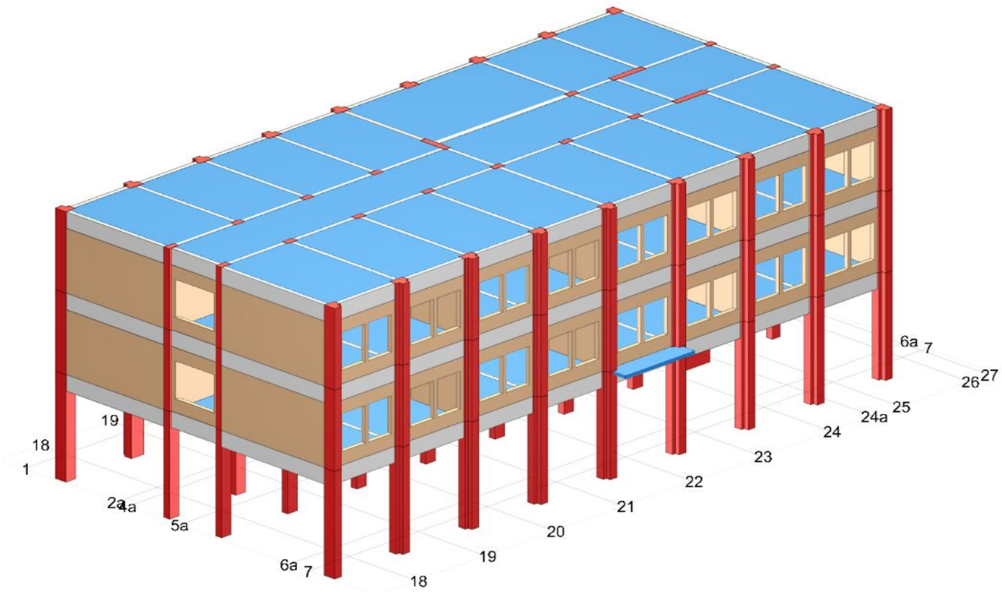

Figure 2.25. 3-D View of Education Building-B

Table 2.13. Base Shear Forces of Education Building-C with RU/LS (F=1.0)

TEC-2007 Design Spectrum				*Site Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	8289.6	2210.6	2210.6	*1*	8289.6	2210.5	2210.6
2	6111.4	3059.3	3059.3	*2*	6111.4	1511.7	1466.8
3	5960.8	5976.8	5976.8	*3*	5960.8	2953.2	2865.7
4	5207.1	8243.2	8243.2	*4*	5207.1	4073.1	3952.4
Σ	25568.8	19489.8	19489.8	Σ	25568.8	10748.5	10495.5
[T_A=0.20, T_B=0.90]				*[T_A=0.13, T_B=0.26]*			
[Performance Status : RU and LS, F=1.0] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.2827, T_y=0.3216]							

Table 2.14. Base Shear Forces of Education Building-C with LS (F=1.5)

TEC-2007 Design Spectrum				*Site Specific Design Spectrum*			
Storey	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**	**Storey**	**Weight (kN)**	**Force-X (kN)**	**Force-Y (kN)**
1	8289.6	2210.6	2210.6	*1*	8289.6	2210.5	2210.6
2	6111.4	4588.9	4588.9	*2*	6111.4	2267.5	2200.2
3	5960.8	8965.1	8965.1	*3*	5960.8	4429.8	4298.6
4	5207.1	12364.9	12364.9	*4*	5207.1	6109.7	5928.6
Σ	25568.8	28129.5	28129.5	Σ	25568.8	15017.5	14622.7
[T_A=0.20, T_B=0.90]				*[T_A=0.13, T_B=0.26]*			
[Performance Status : LS, F=1.5] [R=1, A_0=0.4, I=1, n=0.6] [T_x=0.2827, T_y=0.3216]							

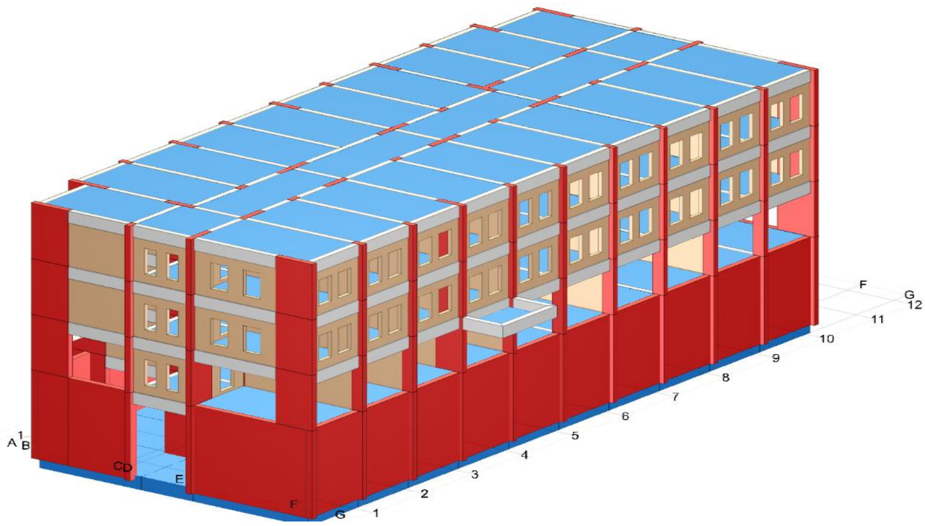

Figure 2.26. 3-D View of Education Building-C

2.3. Limits of Damage in Structural Elements and Areas of Damage

2.3.1. Damage limits in cross sections and sectional damaged areas

Three boundary conditions are defined at member's cross-sections for ductile elements. These are Minimum Damage Limit (RU), Safety Limit (LS) and Collapsing Limit (PC).

Also, elements of damages with critical sections that do not reach the RU are accepted in the Minimum Damage Zone (MDZ), elements between RU and LS are accepted in the Significant Damage Zone (SDZ), those between LS and PC are within Advanced Damage Zone (ADZ) and those going beyond PC are within Collapsing Zone (CZ). In addition, this schema does not apply to brittle elements

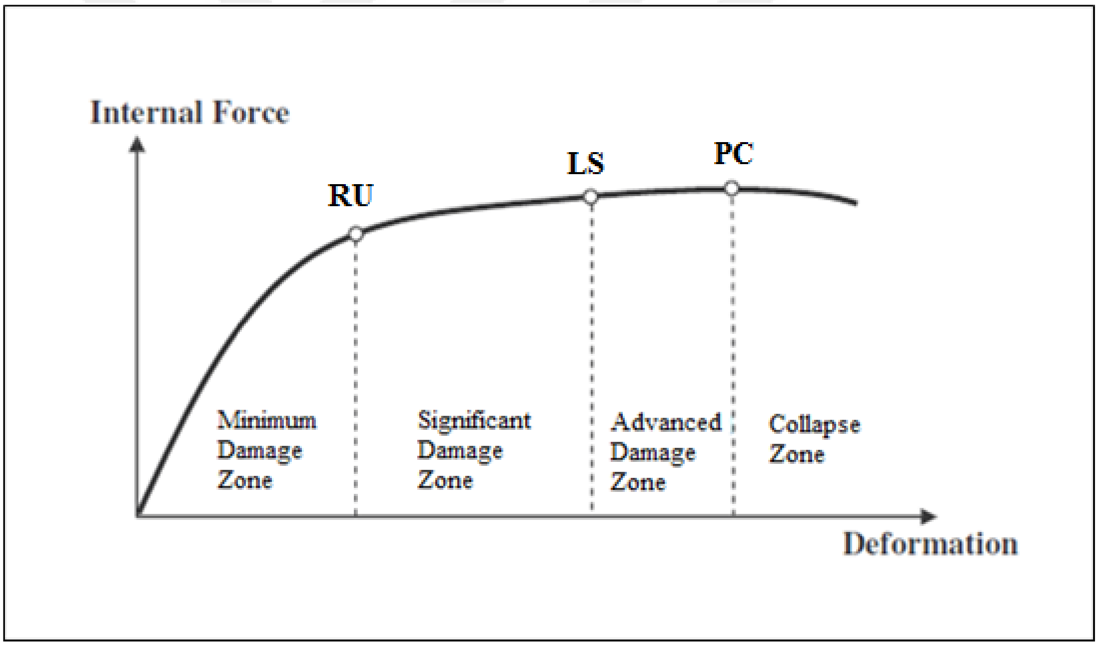

Figure 2.27. Sectional Damage Zones (TEC, 2007)

2.4. Determining the Seismic Performance of a Building

In this study, seismic performance of the buildings is determined with linear elastic calculation method. Seismic performance of the buildings is related to the expected damage cases according to earthquake and building performance level is determined by determining these damage cases. Also, these building performance levels are defined as Ready to Use (RU), Life Safety (LS), Pre-Collapse (PC) and Collapse Level in chapter 7.7 of TEC-2007.

As a result of calculations for each earthquake direction applied to any storeys,

For Ready to Use (RU) performance level:

- At most 10% of beams can be exceed SDZ.
- Other load-bearing structural elements must be in MDZ.
- Brittle damaged elements must be strengthened for RU performance level.

For Life Safety (LS) performance level:

- At most 30% of beams can be exceed ADZ .
- Total contribution of the columns to shear force must not exceed 20% in ADZ except top storey, can be up to 40% at top storey.
- Above condition can be 30% for columns exceeding MDZ with normal ductility level.
- Other load-bearing structural elements must be in MDZ or SDZ.
- Brittle damaged elements must be strengthened for LS performance level.

For Pre-Collapse (PC) performance level:

- At most 30% of beams can be exceed CZ.
- Total contribution of the columns to shear force must not exceed 30% for columns exceeding MDZ with normal ductility level.
- Other load-bearing structural elements must be in MDZ, SDZ or ADZ.
- Brittle damaged elements must be considered in CZ for PC performance level.

For Collapse level:

- Building does not provide PC performance level and its use is detrimental to life safety.

2.5 Targeted Performance Levels for the Buildings

Newly built buildings are based on earthquake with probability of exceeding 10% (F=1) in 50 years with TEC-2007 design spectrum. Also, probability of exceeding 2% (F=1.5) and 50% (F=0.5) are used for performance evaluation and strengthening of existing buildings.

In this context, the seismic levels to be considered in determining seismic performance of existing or strengthened buildings and their minimum performance targets are given in Table 2.15.

In addition, within the scope of this study, earthquake with probability of exceeding 10% in 50 years has also been used for education building at LS performance level. This performance level is not defined in TEC-2007; it is proposed in this study to be able to make more economical decisions about strengthening works for education buildings. As an example, if an education building does not meet the criteria given in TEC-2007; this proposed performance limit is investigated; if the building meets this level, then the strengthening works for this education building can be delayed until after more urgent strengthening works are completed.

Table 2.15. Minimum Building Performance for the Earthquake Levels (TEC, 2007)

The Usage Purpose and The Type of the Building	Probability for the Earthquake to be Exceeded		
	50% in 50 years	10% in 50 years	2% in 50 years
The buildings that should be used after earthquakes: *Hospitals, health facilities, fire stations, communications and energy facilities, transportation stations etc.*	-	RU	LS
The buildings that people stay in for a long time period: *Schools, accommodations, dormitories, pensions, military posts, prisons, museums, etc.*	-	RU	LS
The buildings that people visit densely and stay in for a short time period: *Cinema, theatre and concert halls, culture centers, sports facilities*	RU	LS	-
Buildings containing hazardous materials: *The buildings containing toxic, flammable and explosive materials and the buildings in which the mentioned materials are stored.*	-	RU	PC
Other buildings: *The buildings that does not fit the definitions given above (houses, offices, hotel, tourist facilities, industrial buildings, etc.)*	-	LS	-

2.6 Determining the Building Performance in Earthquake with Equivalent Seismic Load Method

2.6.1. Calculation Method

Equivalent seismic load method from linear calculation methods is defined in section 2.2.2.

When calculating equivalent seismic load, the following cases should be observed:

- Buildings not exceed 25m and 8 storeys.
- $\eta_{bi} < 1.4$ calculated without considering eccentricity.
- R_a is taken as “1” in equation (2.3)
- Right side of the equation (2.3) is multiplied with λ factor that is taken as 1.0 for one and two storey buildings except cellar and 0.85 to other storey buildings.

2.6.2. Upper limit of effect/capacity on structural elements

Upper limit in case of tension or compression of N_K axial force can be defined as axial force obtained at relevant column as a result of transferring V_E shear forces to columns, which is calculated in accordance with direction of the earthquake.

On the other hand, if transverse reinforcement conditions are met in the confinement zone, the columns, beams and shear walls are considered as "confined", while those that do not have confinement reinforcement are considered as "unconfined". It is necessary for the elements that are considered as “confined” to meet the conditions as defined in section 3.3.4 – section 3.4.4 of TEC-2007.

Table 2.16. Effect/Capacity Ratios (rs) Defines the Boundary of the Damage for Beams (TEC, 2007)

Ductile Beams			Damage Boundary		
$\frac{\rho - \rho'}{\rho_b}$	Confinement	$\frac{V}{b_w d\, f_{ctm}}$	RU	LS	PC
≤ 0.0	Available	≤ 0.65	3	7	10
≤ 0.0	Available	≥ 1.30	2.5	5	8
≥ 0.5	Available	≤ 0.65	3	5	7
≥ 0.5	Available	≥ 1.30	2.5	4	5
≤ 0.0	Not available	≤ 0.65	2.5	4	6
≤ 0.0	Not available	≥ 1.30	2	3	5
≥ 0.5	Not available	≤ 0.65	2.5	4	6
≥ 0.5	Not available	≥ 1.30	1.5	2.5	4

Table 2.17. Effect/Capacity Ratios (r_s) Defines the Boundary of the Damage for Columns (TEC, 2007)

Ductile Columns			Damage Boundary		
$\frac{N}{A_c f_c}$	Confinement	$\frac{V}{b_w d\, f_{ctm}}$	RU	LS	PC
≤ 0.1	Available	≤ 0.65	3	6	8
≤ 0.1	Available	≥ 1.30	2.5	5	6
≥ 0.4	Available	≤ 0.65	2	4	6
≥ 0.4	Available	≥ 1.30	2	3	5
≤ 0.1	Not available	≤ 0.65	2	3.5	5
≤ 0.1	Not available	≥ 1.30	1.5	2.5	3.5
≥ 0.4	Not available	≤ 0.65	1.5	2	3
≥ 0.4	Not available	≥ 1.30	1	1.5	2

Table 2.18. Effect/Capacity Ratios (r_s) Defines the Boundary of the Damage for Shear Walls (TEC, 2007)

Ductile Shear Walls	Damage Boundary		
Confinement	RU	LS	PC
Available	3	6	8
Not Available	2	4	6

2.8. Horizontal Displacements

It is well known that earthquake loads have much greater effects in horizontal displacements of structures. Therefore, horizontal displacements of top corners of the education buildings are examined with DX± and DY± load cases.

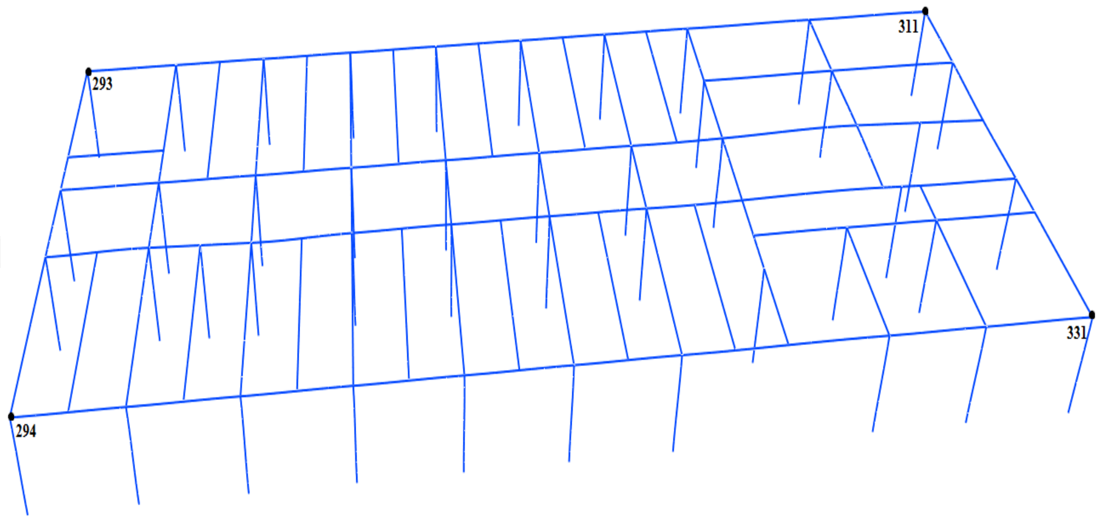

Figure 2.28. Corner Points are Examined on Top Floor for Education Building-A

Table 2.19. Horizontal Displacements for Education Building-A

		LS-(2% in 50 Years) F=1.5		*RU/LS-(10% in 50 Years) F=1.0*	
	Joint No	**DX± (mm)**	**DY± (mm)**	**DX± (mm)**	**DY± (mm)**
TEC-2007 Design Spectrum	293	35.03	42.92	23.35	28.61
	294	38.55	42.92	25.70	28.61
	311	35.03	36.26	23.35	24.17
	331	38.55	36.26	25.70	24.17
Site-Specific Design Spectrum	293	15.23	18.66	10.15	12.44
	294	16.76	18.66	11.17	12.44
	311	15.23	15.76	10.15	10.51
	331	16.76	15.76	11.17	10.51

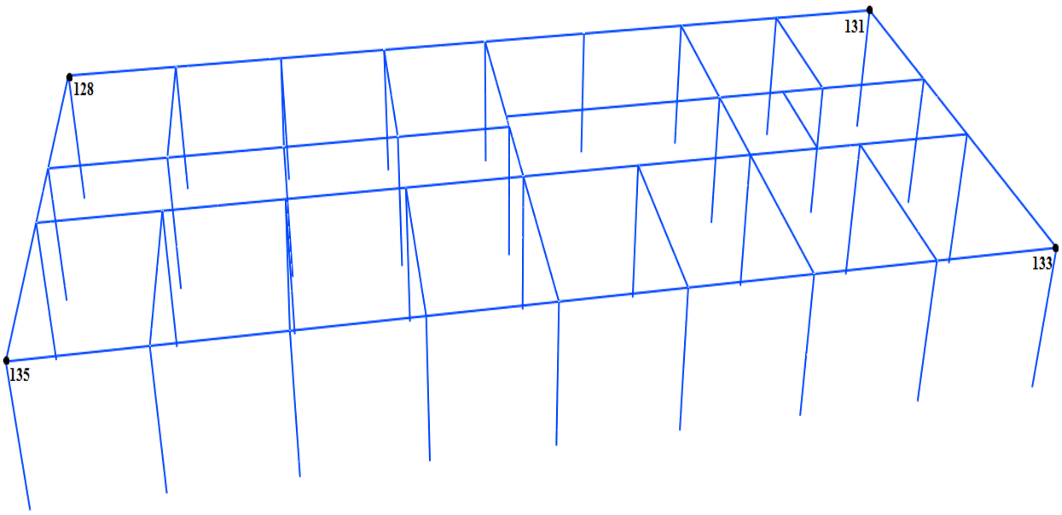

Figure 2.29. Corner Points are Examined on Top Floor for Education Building-B

Table 2.20. Horizontal Displacements for Education Building-B

		LS-(2% in 50 Years) F=1.5		*RU/LS-(10% in 50 Years) F=1.0*	
	Joint No	**DX± (mm)**	**DY± (mm)**	**DX± (mm)**	**DY± (mm)**
TEC-2007 Design Spectrum	128	56.20	130.05	37.47	86.70
	135	57.10	130.05	38.07	86.70
	131	56.20	124.20	37.47	82.80
	133	57.10	124.20	38.07	82.80
Site-Specific Design Spectrum	128	27.17	56.13	18.11	37.42
	135	27.60	56.13	18.40	37.42
	131	27.17	53.61	18.11	35.74
	133	27.60	53.61	18.40	35.74

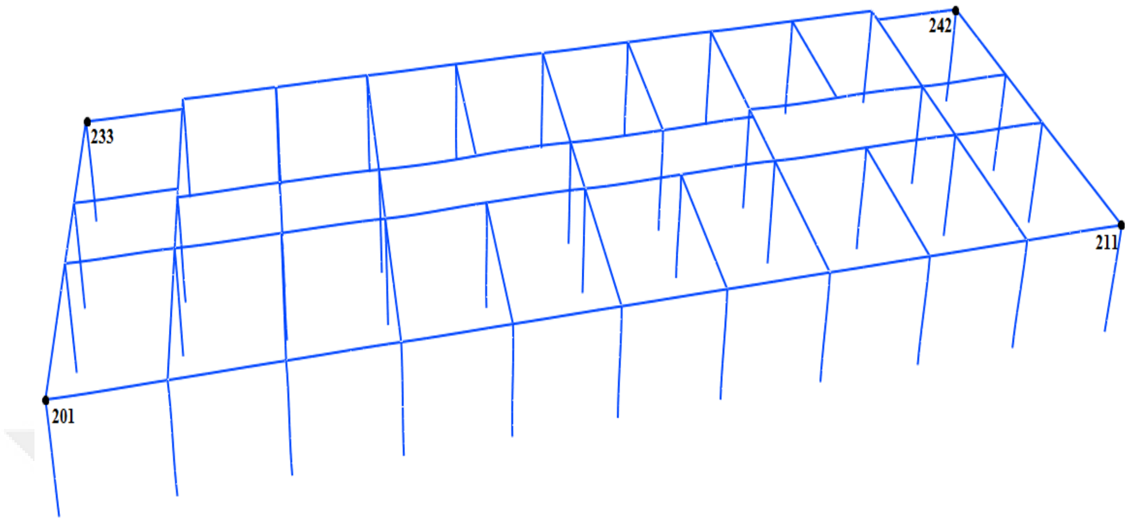

Figure 2.30. Corner Points are Examined on Top Floor for Education Building-C

Table 2.21. Horizontal Displacements for Education Building-C

		LS-(2% in 50 Years) F=1.5		*RU/LS-(10% in 50 Years) F=1.0*	
	Joint No	**DX± (mm)**	**DY± (mm)**	**DX± (mm)**	**DY± (mm)**
TEC-2007 Design Spectrum	233	45.54	55.98	30.36	37.32
	201	45.07	55.98	30.05	37.32
	242	45.54	63.06	30.36	42.04
	211	45.07	63.06	30.05	42.04
Site-Specific Design Spectrum	233	22.62	27.09	15.08	18.06
	201	22.39	27.09	14.93	18.06
	242	22.62	30.44	15.08	20.29
	211	22.39	30.44	14.93	20.29

3. EVALUATIONS OF THE SEISMIC PERFORMANCES OF EDUCATION BUILDINGS

According to TEC-2007 information annex 7A, moment and normal force capacities of columns and shear walls are calculated according to earthquake direction for Ready to Use (10% in 50 years) and Life Safety (2% in 50 years). In this study, another performance level is proposed in which Life Safety (10% in 50 years) for earthquake evaluations of education buildings are also considered.

Probina Orion 2013 gives results of damage status for all earthquake directions (Prota, 2018). However, one beam, column and shear wall were presented as an example in the following tables. As a result, the performance levels of load-bearing structural elements are given only for education building-A depending on the TEC design spectrum and site-specific design spectrum.

3.1. Determination and Evaluation of Damage Status in Columns

As an example, if the damage status of the 4th storey S21 column of education building-A for RU (10% in 50 years) was examined according to +X earthquake direction. The following results were obtained for TEC design spectrum and site-specific design spectrum.

Table 3.1. Column Information to Damage Status according to TEC Design Spectrum

Column Name	b (cm)	d (cm)	As + Ag	N_d (kN)	N_e (kN)	V_e (kN)	$\frac{N_k}{A_c f_{cm}}$	$\frac{V_e}{b_w d f_{cm}}$	r
S21	30	60	12Ø16	96.65	-11.81	43.78	0.06	0.26	2.02 2.24

Table 3.2. Column Information to Damage Status according to Site-Specific Design Spectrum

Column Name	b (cm)	d (cm)	As + Ag	N_d (kN)	N_e (kN)	V_e (kN)	$\frac{N_k}{A_c f_{cm}}$	$\frac{V_e}{b_w d f_{cm}}$	r
S21	30	60	12Ø16	96.65	-11.81	23.94	0.06	0.14	1.00
									1.10

According to TEC-2007 column effect/capacity Table 2.17. with +X earthquake direction, the following results were obtained.

Table 3.3. Damage Status of S21 According to +X Direction and TEC Design Spectrum

Column Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
S21	2	3.5	5	2.02	SDZ	SDZ
				2.24	SDZ	

Table 3.4. Damage Status of S21 According to +X Direction and Site-Specific Design Spectrum

Column Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
S21	2	3.5	5	1.00	MDZ	MDZ
				1.10	MDZ	

3.2. Determination and Evaluation of Damage Status in Shear Walls

When the damage status of the 1st storey P6 shear wall of education building-A for RU (10% in 50 years) was examined according to the +X earthquake direction as an example, the following results were obtained for TEC design spectrum and site-specific design spectrum.

Table 3.5. Shear Wall Information to Damage Status according to TEC Design Spectrum

Shear Wall Name	b_w (cm)	l_w (cm)	As + Ag	V_e (kN)	V_r (kN)	Breaking Type	r
P6	30	360	14Ø16 26Ø12	1289.24	956.98	$V_e > V_r$	1.35
						Brittle	1.35

Table 3.6. Shear Wall Information to Damage Status according to Site-Specific Design Spectrum

Shear Wall Name	b_w (cm)	l_w (cm)	As + Ag	V_e (kN)	V_r (kN)	Breaking Type	r
P6	30	360	14Ø16 26Ø12	688.19	957.18	$V_e < V_r$	0.72
						Ductile	0.72

According to TEC-2007 shear wall effect/capacity Table 2.18. with +X earthquake direction, the following results were obtained.

Table 3.7. Damage Status of P6 According to +X Direction and TEC Design Spectrum

Shear Wall Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
P6	2	4	6	1.35	MDZ	MDZ
				1.35	MDZ	

Table 3.8. Damage Status of P6 According to +X Direction and Site-Specific Design Spectrum

Shear Wall Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
P6	2	4	6	0.72	MDZ	MDZ
				0.72	MDZ	

3.3. Determination and Evaluation of Damage Status in Beams

Shear safety for beams shall be done according to TEC-2007 section 3.4.5. In this context, the following example was examined for 1st storey K134 beam of education building-A for RU (10% in 50 years) according to the +X earthquake direction.

Table 3.9. Beam Information to Damage Status according to TEC Design Spectrum

Beam Name	b_w (cm)	d (cm)	l_{net} (cm)	V_e (kN)	V_r (kN)	$\frac{\rho - \rho'}{\rho_b}$	$\frac{V_e}{b_w d f_{cm}}$	r
K134	30	70	230	47.33	175.97	0.05	0.23	2.24
				107.94		-0.05	0.52	4.33

Table 3.10. Beam Information to Damage Status according to Site-Specific Design Spectrum

Beam Name	b_w (cm)	d (cm)	l_{net} (cm)	V_e (kN)	V_r (kN)	$\frac{\rho - \rho'}{\rho_b}$	$\frac{V_e}{b_w d f_{cm}}$	r
K134	30	70	230	47.33	175.97	0.05	0.23	1.13
				107.94		-0.05	0.52	2.18

According to TEC-2007 beam effect/capacity Table 2.16. with +X earthquake direction, the following results were obtained.

Table 3.11. Damage Status of K134 According to +X Direction and TEC Design Spectrum

Beam Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
K134	2.5	4	6	2.24	MDZ	ADZ
				4.33	ADZ	

Table 3.12. Damage Status of K134 According to +X Direction and Site-Specific Design Spectrum

Beam Name	RU	LS	PC	r	End Acceptance	Str. Element Acceptance
K134	2.5	4	6	1.13	MDZ	MDZ
				2.18	MDZ	

3.4. Control of Relative Storey Drifts

Due to the fact that the examined structures are schools, the probability of exceeding 10% in 50 years is required to ready to use (RU) and the probability of exceeding %2 in 50 years is required to life safety (LS), otherwise the performance evaluation according to section 2.6.2 is said to be “non-satisfactory”. Detailed checks were presented only for education building-A and direct results were given for the other two education buildings in Table 3.22.

Table 3.13. Boundaries of Relative Storey Drifts (TEC, 2007)

Ratio of Relative Storey Drift	Damage Boundary		
	RU	LS	PC
δ_{ji} / h_{ji}	0.01	0.03	0.04

Table 3.14. X Earthquake Direction Relative Storey Drifts of Education Building-A According to TEC Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	RU	Conformance
1	3.45	0.0101	0.0101	0.0101	0.0029	0.01	< RU
2	3.15	0.0226	0.0126	0.0126	0.0040	0.01	< RU
3	3.15	0.0350	0.0126	0.0126	0.0040	0.01	< RU
4	3.15	0.0453	0.0106	0.0106	0.0034	0.01	< RU

Table 3.15. Y Earthquake Direction Relative Storey Drifts of Education Building-A According to TEC Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	RU	Conformance
1	3.45	0.0319	0.0319	0.0319	0.0092	0.01	< RU
2	3.15	0.0720	0.0302	0.0302	0.0096	0.01	< RU
3	3.15	0.1063	0.0242	0.0242	0.0077	0.01	< RU
4	3.15	0.1306	0.0245	0.0245	0.0078	0.01	< RU

Table 3.16. X Earthquake Direction Relative Storey Drifts of Education Building-A According to TEC Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	LS	Conformance
1	3.45	0.0152	0.0152	0.0152	0.0044	0.03	< LS
2	3.15	0.0339	0.0189	0.0189	0.0060	0.03	< LS
3	3.15	0.0525	0.0190	0.0190	0.0060	0.03	< LS
4	3.15	0.0679	0.0160	0.0160	0.0051	0.03	< LS

Table 3.17. Y Earthquake Direction Relative Storey Drifts of Education Building-A According to TEC Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	LS	Conformance
1	3.45	0.0479	0.0479	0.0479	0.0139	0.03	< LS
2	3.15	0.1080	0.0604	0.0604	0.0192	0.03	< LS
3	3.15	0.1594	0.0513	0.0513	0.0163	0.03	< LS
4	3.15	0.1960	0.0367	0.0367	0.0116	0.03	< LS

Table 3.18. X Earthquake Direction Relative Storey Drifts of Education Building-A According to Site-Specific Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	RU	Conformance
1	3.45	0.0059	0.0059	0.0059	0.0017	0.01	< RU
2	3.15	0.0130	0.0073	0.0073	0.0023	0.01	< RU
3	3.15	0.0202	0.0073	0.0073	0.0023	0.01	< RU
4	3.15	0.0261	0.0061	0.0061	0.0019	0.01	< RU

Table 3.19. Y Earthquake Direction Relative Storey Drifts of Education Building-A According to Site-Specific Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	RU	Conformance
1	3.45	0.0185	0.0185	0.0185	0.0054	0.01	< RU
2	3.15	0.0418	0.0233	0.0233	0.0074	0.01	< RU
3	3.15	0.0616	0.0198	0.0198	0.0063	0.01	< RU
4	3.15	0.0757	0.0142	0.0142	0.0045	0.01	< RU

Table 3.20. X Earthquake Direction Relative Storey Drifts of Education Building-A According to Site-Specific Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	LS	Conformance
1	3.45	0.0088	0.0088	0.0088	0.0025	0.03	< LS
2	3.15	0.0196	0.0109	0.0109	0.0035	0.03	< LS
3	3.15	0.0303	0.0109	0.0109	0.0035	0.03	< LS
4	3.15	0.0392	0.0092	0.0092	0.0029	0.03	< LS

Table 3.21. Y Earthquake Direction Relative Storey Drifts of Education Building-A According to Site-Specific Design Spectrum

Storey	Storey Height	$d_{i,max}$ (m)	$\Delta_{i,max}$ (m)	$\delta_{i,max}$ (m)	$\delta_{i,max}/h_i$ (m)	LS	Conformance
1	3.45	0.0277	0.0277	0.0277	0.0080	0.03	< LS
2	3.15	0.0626	0.0350	0.0350	0.0111	0.03	< LS
3	3.15	0.0924	0.0298	0.0298	0.0094	0.03	< LS
4	3.15	0.1136	0.0213	0.0213	0.0067	0.03	< LS

Table 3.22. Direct Results of Relative Storey Drifts for Education Buildings-B/C

		TEC-2007 Design Spectrum		Site-Specific Design Spectrum	
		RU	LS	RU	LS
Education Building-B	**X Direction**	√	√	√	√
	Y Direction	√	√	√	√
Education Building-C	**X Direction**	√	√	√	√
	Y Direction	√	√	√	√

3.5. Earthquake Performance Evaluations of Buildings

The earthquake performance evaluation of the beams, columns and shear walls belonging to the education buildings shall be made in accordance with section 2.4 of this thesis.

In this context, results of the calculations regarding all earthquakes applied in any floors, at most 10% of the beams exceed the SDZ and all other load-bearing components remain in the MDZ according to ready to use performance level. On the other hand, as the result of the calculations made for each earthquake direction applies on each floor, at most 30% of the beams can exceed the ADZ. Also, total contribution of the columns in the ADZ to the shear force that is borne by the columns in each floor should not exceed 20%. For the top floor, the ratio of the total shear forces of the columns in the SDZ to the total shear forces of all the columns at that floor can be at most 40%. (Columns are including shear walls)

On the other hand, all earthquake directions and design spectra (TEC and SSS) were taken as basis on determination of performance levels of load-bearing structural elements. These were examined in following tables in detail and direct results were given for all education buildings in Table 3.95.

Table 3.23. RU Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	%of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	8	17.78	27630.9	12592.7	45.57	> 0.00
Beams		40	18	45	-	-		> 10.00
Columns	2	45	7	15.56	24648.8	7386.6	29.97	> 0.00
Beams		40	23	57.5	-	-		> 10.00
Columns	3	45	5	11.11	18967.9	2030.6	10.71	> 0.00
Beams		40	25	62.5	-	-		> 10.00
Columns	4	45	5	11.11	10542.8	1017.3	9.65	> 0.00
Beams		40	9	22.5	-	-		> 10.00

Table 3.24. RU Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	%of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	7	15.56	27630.9	12073.1	43.69	> 0.00
Beams		40	17	42.5	-	-		> 10.00
Columns	2	45	7	15.56	24648.8	7083.7	28.74	> 0.00
Beams		40	21	52.5	-	-		> 10.00
Columns	3	45	5	11.11	18967.9	1853.3	9.77	> 0.00
Beams		40	25	62.5	-	-		> 10.00
Columns	4	45	4	8.89	10542.8	917.5	8.70	> 0.00
Beams		40	9	22.5	-	-		> 10.00

Table 3.25. RU Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	13	28.89	27630.9	14173.2	51.29	> 0.00
Beams		35	18	51.43	-	-		> 10.00
Columns	2	45	14	31.11	24648.8	8109.6	32.9	> 0.00
Beams		35	24	68.57	-	-		> 10.00
Columns	3	45	9	20.00	18967.9	2983.7	15.73	> 0.00
Beams		35	27	77.14	-	-		> 10.00
Columns	4	45	8	17.78	10542.8	1487.3	14.11	> 0.00
Beams		35	12	34.29	-	-		> 10.00

Table 3.26. RU Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	13	28.89	27630.9	14173.2	51.29	> 0.00
Beams		35	18	51.43	-	-		> 10.00
Columns	2	45	14	31.11	24648.8	8109.6	32.9	> 0.00
Beams		35	24	68.57	-	-		> 10.00
Columns	3	45	10	22.22	18967.9	3135.7	16.53	> 0.00
Beams		35	23	65.71	-	-		> 10.00
Columns	4	45	9	20.00	10542.8	1567.3	14.87	> 0.00
Beams		35	11	31.43	-	-		> 10.00

Table 3.27. LS Performance Status (2% in 50 Years) of Education Building-A with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	8	17.78	41446.3	18887.1	45.57	> 20.00
Beams		40	15	37.5		-		> 30.00
Columns	2	45	6	13.33	36973.2	10226.8	27.66	> 20.00
Beams		40	23	57.5		-		> 30.00
Columns	3	45	2	4.44	28451.9	1118.2	3.93	< 20.00
Beams		40	23	57.5		-		> 30.00
Columns	4	45	1	2.22	15814.2	844.5	5.34	< 40.00
Beams		40	5	12.5		-		< 30.00

Table 3.28. LS Performance Status (2% in 50 Years) of Education Building-A with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	9	20.00	41446.3	19641.4	47.39	> 20.00
Beams		40	13	32.50		-		> 30.00
Columns	2	45	5	11.11	36973.2	9306.2	25.17	> 20.00
Beams		40	19	47.50		-		> 30.00
Columns	3	45	2	4.44	28451.9	1118.2	3.93	< 20.00
Beams		40	21	52.50		-		> 30.00
Columns	4	45	1	2.22	15814.2	844.5	5.34	< 40.00
Beams		40	3	7.50		-		< 30.00

Table 3.29. LS Performance Status (2% in 50 Years) of Education Building-A with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	14	31.11	41446.3	21908.5	52.86	> 20.00
Beams		35	18	51.43		-		> 30.00
Columns	2	45	14	31.11	36973.2	12164.2	32.9	> 20.00
Beams		35	24	68.57		-		> 30.00
Columns	3	45	9	20.00	28451.9	4475.5	15.73	< 20.00
Beams		35	27	77.14		-		> 30.00
Columns	4	45	8	17.78	15814.2	2231.4	14.11	< 40.00
Beams		35	10	28.57		-		< 30.00

Table 3.30. LS Performance Status (2% in 50 Years) of Education Building-A with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	12	26.67	41446.3	22037.0	53.17	> 20.00
Beams		35	17	48.57		-		> 30.00
Columns	2	45	13	28.89	36973.2	11387.7	30.8	> 20.00
Beams		35	21	60.00		-		> 30.00
Columns	3	45	9	20.00	28451.9	4424.3	15.55	< 20.00
Beams		35	23	65.71		-		> 30.00
Columns	4	45	2	4.44	15814.2	1992.6	12.6	< 40.00
Beams		35	5	14.29		-		< 30.00

Table 3.31. LS Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	4	8.89	27630.9	8206.4	29.7	> 20.00
Beams		40	4	10	-	-		< 30.00
Columns	2	45	2	4.44	24648.8	4456.5	18.08	< 20.00
Beams		40	11	27.5	-	-		< 30.00
Columns	3	45	0	0	18967.9	0	0	< 20.00
Beams		40	11	27.5	-	-		< 30.00
Columns	4	45	0	0	10542.8	0	0	< 40.00
Beams		40	3	7.5	-	-		< 30.00

Table 3.32. LS Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	3	6.67	27630.9	7291.8	26.39	> 20.00
Beams		40	4	10	-	-		< 30.00
Columns	*2*	45	2	4.44	24648.8	4456.5	18.08	< 20.00
Beams		40	9	22.5	-	-		< 30.00
Columns	*3*	45	0	0	18967.9	0.	0	< 20.00
Beams		40	8	20	-	-		< 30.00
Columns	*4*	45	0	0	10542.8	0	0	< 40.00
Beams		40	2	5	-	-		< 30.00

Table 3.33. LS Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	7	15.56	27630.9	12124.4	43.88	> 20.00
Beams		35	12	34.29	-	-		> 30.00
Columns	*2*	45	10	22.22	24648.8	6778.4	27.5	> 20.00
Beams		35	20	57.14	-	-		> 30.00
Columns	*3*	45	4	6.67	18967.9	1297.4	6.84	< 20.00
Beams		35	13	37.14	-	-		> 30.00
Columns	*4*	45	2	4.44	10542.8	505.0	4.79	< 40.00
Beams		35	8	22.86	-	-		< 30.00

Table 3.34. LS Performance Status (10% in 50 Years) of Education Building-A with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	8	17.78	27630.9	12627.3	45.7	> 20.00
Beams		35	13	37.14	-	-		> 30.00
Columns	*2*	45	10	22.22	24648.8	6778.4	27.5	> 20.00
Beams		35	19	54.29	-	-		> 30.00
Columns	*3*	45	3	6.67	18967.9	1098.2	5.79	< 20.00
Beams		35	9	25.71	-	-		< 30.00
Columns	*4*	45	2	4.44	10542.8	570.4	5.41	< 40.00
Beams		35	9	25.71	-	-		< 30.00

Table 3.35. RU Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	0	0	15938.8	0	0	< 0.00
Beams		40	1	2.5		-		< 10.00
Columns	2	45	0	0	14218.6	0	0	< 0.00
Beams		40	3	7.5		-		< 10.00
Columns	3	45	0	0	10941.6	0	0	< 0.00
Beams		40	1	2.5		-		< 10.00
Columns	4	45	0	0	6081.6	0	0	< 0.00
Beams		40	1	2.5		-		< 10.00

Table 3.36. RU Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	0	0	15938.8	0	0	< 0.00
Beams		40	1	2.5		-		< 10.00
Columns	2	45	0	0	14218.6	0	0	< 0.00
Beams		40	3	7.5		-		< 10.00
Columns	3	45	0	0	10941.6	0	0	< 0.00
Beams		40	2	5		-		< 10.00
Columns	4	45	0	0	6081.6	0	0	< 0.00
Beams		40	2	5		-		< 10.00

Table 3.37. RU Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	0	0	16020.1	0	0	< 0.00
Beams		35	2	5.71	-	-		< 10.00
Columns	2	45	0	0	14216.5	0	0	< 0.00
Beams		35	3	8.57	-	-		< 10.00
Columns	3	45	0	0	10940.0	0	0	< 0.00
Beams		35	3	8.57	-	-		< 10.00
Columns	4	45	0	0	6080.7	0	0	< 0.00
Beams		35	3	8.57	-	-		< 10.00

Table 3.38. RU Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	0	0	16020.1	0	0	< 0.00
Beams		35	2	5.71	-	-		< 10.00
Columns	2	45	0	0	14216.5	0	0	< 0.00
Beams		35	2	5.71	-	-		< 10.00
Columns	3	45	0	0	10940.0	0	0	< 0.00
Beams		35	3	8.57	-	-		< 10.00
Columns	4	45	0	0	6080.7	0	0	< 0.00
Beams		35	2	5.71	-	-		< 10.00

Table 3.39. LS Performance Status (2% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	2	4	23906.1	2364.3	9.89	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	2	45	1	2	21326	1748.7	8.2	< 20.00
Beams		40	5	12.5		-		< 30.00
Columns	3	45	0	0	16410.9	0	0	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	4	45	0	0	9121.6	0	0	< 40.00
Beams		40	2	5		-		< 30.00

Table 3.40. LS Performance Status (2% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	2	4	23906.1	2364.3	9.89	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	2	45	0	0	21326	1748.7	8.2	< 20.00
Beams		40	6	15		-		< 30.00
Columns	3	45	0	0	16410.9	0	0	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	4	45	0	0	9121.6	0	0	< 40.00
Beams		40	1	2.5		-		< 30.00

Table 3.41. LS Performance Status (2% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	5	11	24020.5	4280.5	17.82	< 20.00
Beams		35	9	25.71		-		< 30.00
Columns	2	45	3	7	21428.1	2526.4	11.79	< 20.00
Beams		35	10	28.57		-		< 30.00
Columns	3	45	1	2	16489.5	770	4.67	< 20.00
Beams		35	8	22.86		-		< 30.00
Columns	4	45	0	0	9165.2	0	0	< 40.00
Beams		35	3	8.57		-		< 30.00

Table 3.42. LS Performance Status (2% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	6	13	24020.5	4499.0	18.73	< 20.00
Beams		35	10	28.57		-		< 30.00
Columns	2	45	3	7	21428.1	2526.4	11.79	< 20.00
Beams		35	7	20		-		< 30.00
Columns	3	45	0	0	16489.5	0	0	< 20.00
Beams		35	10	28.57		-		< 30.00
Columns	4	45	0	0	9165.2	0	0	< 40.00
Beams		35	4	11.43		-		< 30.00

Table 3.43. LS Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	45	0	0	15938.8	0	0	< 20.00
Beams		40	2	5		-		< 30.00
Columns	2	45	0	0	14218.6	0	0	< 20.00
Beams		40	5	12.5		-		< 30.00
Columns	3	45	0	0	10941.6	0	0	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	4	45	0	0	6081.6	0	0	< 40.00
Beams		40	3	7.5		-		< 30.00

Table 3.44. LS Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	0	0	15938.8	0	0	< 20.00
Beams		40	3	7.5		-		< 30.00
Columns	*2*	45	0	0	14218.6	0	0	< 20.00
Beams		40	6	15		-		< 30.00
Columns	*3*	45	0	0	10941.6	0	0	< 20.00
Beams		40	2	5		-		< 30.00
Columns	*4*	45	0	0	6081.6	0	0	< 40.00
Beams		40	1	2.5		-		< 30.00

Table 3.45. LS Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	0	0	16020.1	0	0	< 20.00
Beams		35	6	17.14	-	-		< 30.00
Columns	*2*	45	0	0	14216.5	0	0	< 20.00
Beams		35	9	25.71	-	-		< 30.00
Columns	*3*	45	0	0	10940.0	0	0	< 20.00
Beams		35	6	17.14	-	-		< 30.00
Columns	*4*	45	0	0	6080.7	0	0	< 40.00
Beams		35	2	5.71	-	-		< 30.00

Table 3.46. LS Performance Status (10% in 50 Years) of Education Building-A with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	45	0	0	16020.1	0	0	< 20.00
Beams		35	5	14.29	-	-		< 30.00
Columns	*2*	45	0	0	14216.5	0	0	< 20.00
Beams		35	7	20	-			< 30.00
Columns	*3*	45	0	0	10940.0	0	0	< 20.00
Beams		35	7	20	-	-		< 30.00
Columns	*4*	45	0	0	6080.7	0	0	< 40.00
Beams		35	3	8.57	-	-		< 30.00

Table 3.47. RU Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	11694.9	11552.3	98.78	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	*2*	35	20	57.14	9623.2	4806.3	49.94	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	*3*	35	12	34.28	5516.2	1677.1	30.40	> 0.00
Beams		31	31	100.00		-		> 10.00

Table 3.48. RU Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	11694.9	11552.3	98.78	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	*2*	35	22	62.85	9623.2	5038.0	52.35	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	*3*	35	11	31.42	5516.2	1505.1	27.29	> 0.00
Beams		31	31	100.00		-		> 10.00

Table 3.49. RU Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	11694.9	11661.3	99.71	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	*2*	35	29	82.85	9623.2	8391.0	87.20	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	*3*	35	21	60	5516.2	3962.2	71.83	> 0.00
Beams		22	22	100.00		-		> 10.00

Table 3.50. RU Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	34	97.14	11694.9	11674.3	99.82	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	2	35	29	82.85	9623.2	8225.4	85.48	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	3	35	27	77.14	5516.2	4605.7	83.49	> 0.00
Beams		22	22	100.00		-		> 10.00

Table 3.51. LS Performance Status (2% in 50 Years) of Education Building-B with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	34	97.14	17542.3	17328.4	98.78	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	2	35	12	34.28	14434.7	3474.3	24.07	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	3	35	6	17.14	8274.3	1261.4	15.24	< 40.00
Beams		31	31	100.00		-		> 30.00

Table 3.52. LS Performance Status (2% in 50 Years) of Education Building-B with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	34	97.14	17542.3	17328.4	98.78	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	2	35	12	34.29	14434.7	3474.3	24.07	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	3	35	6	17.14	8274.3	1219.6	14.74	< 40.00
Beams		31	31	100.00		-		> 30.00

Table 3.53. LS Performance Status (2% in 50 Years) of Education Building-B with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	17542.3	17418.3	99.29	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*2*	35	19	54.29	14434.7	8767.3	60.74	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	18	51.43	8274.3	5297.8	64.03	> 40.00
Beams		22	22	100.00		-		> 30.00

Table 3.54. LS Performance Status (2% in 50 Years) of Education Building-B with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	17542.3	17407.2	99.23	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*2*	35	24	68.57	14434.7	10444.4	72.36	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	24	68.57	8274.3	6200.8	74.94	> 40.00
Beams		22	22	100.00		-		> 30.00

Table 3.55. LS Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	14	40	11694.9	5885.7	50.33	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*2*	35	11	31.42	9623.2	2125.3	22.09	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*3*	35	2	5.71	5516.2	371.8	6.74	< 40.00
Beams		31	20	64.52		-		> 30.00

Table 3.56. LS Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	14	40	11694.9	5919.6	50.62	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*2*	35	8	22.85	9623.2	1690.0	17.56	< 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*3*	35	0	0	5516.2	0	0	< 40.00
Beams		31	20	64.52		-		> 30.00

Table 3.57. LS Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	11694.9	11637.2	99.51	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*2*	35	16	45.71	9623.2	4867.9	50.58	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	12	34.28	5516.2	2216.6	40.18	> 40.00
Beams		22	19	86.36		-		> 30.00

Table 3.58. LS Performance Status (10% in 50 Years) of Education Building-B with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	34	97.14	11694.9	11598.3	99.17	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*2*	35	16	45.71	9623.2	4835.5	50.25	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	10	28.57	5516.2	1790.2	32.45	< 40.00
Beams		22	21	95.45		-		> 30.00

Table 3.59. RU Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	4	11.43	5526.0	2019.7	36.55	> 0.00
Beams		31	30	96.77		-		> 10.00
Columns	2	35	2	5.71	4547.1	250.2	5.50	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	3	35	1	2.86	2606.5	81.2	3.12	> 0.00
Beams		31	4	12.90		-		> 10.00

Table 3.60. RU Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	3	8.57	5526.0	1916.3	34.68	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	2	35	1	2.86	4547.1	132.3	2.91	> 0.00
Beams		31	31	100.00		-		> 10.00
Columns	3	35	0	0	2606.5	0	0	< 0.00
Beams		31	3	9.68		-		< 10.00

Table 3.61. RU Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	35	28	80.00	4869.4	4118.8	84.58	> 0.00
Beams		22	21	95.45		-		> 10.00
Columns	2	35	11	31.43	4006.8	1048.1	26.16	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	3	35	10	28.57	2296.7	711.5	30.98	> 0.00
Beams		22	17	77.27		-		> 10.00

Table 3.62. RU Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	22	62.86	4869.4	3258.5	66.92	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	*2*	35	10	28.57	4006.8	985.4	24.59	> 0.00
Beams		22	22	100.00		-		> 10.00
Columns	*3*	35	9	25.71	2296.7	666.4	29.02	> 0.00
Beams		22	17	77.27		-		> 10.00

Table 3.63. LS Performance Status (2% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	4	11.43	8289.0	3029.6	36.55	> 20.00
Beams		31	30	96.77		-		> 30.00
Columns	*2*	35	2	5.71	6820.6	375.2	5.50	< 20.00
Beams		31	30	96.77		-		> 30.00
Columns	*3*	35	1	2.86	3909.7	121.9	3.12	< 40.00
Beams		31	4	12.90		-		< 30.00

Table 3.64. LS Performance Status (2% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	4	11.43	8289.0	2998.0	36.17	> 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*2*	35	1	2.86	6820.6	198.4	2.91	< 20.00
Beams		31	31	100.00		-		> 30.00
Columns	*3*	35	0	0	3909.7	0	0	< 40.00
Beams		31	2	6.45		-		< 30.00

Table 3.65. LS Performance Status (2% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	14	40.00	7304.1	3048.7	41.74	> 20.00
Beams		22	21	95.45		-		> 30.00
Columns	*2*	35	11	31.43	6010.2	1572.1	26.16	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	9	25.71	3445.2	940.0	27.28	< 40.00
Beams		22	17	77.27		-		> 30.00

Table 3.66. LS Performance Status (2% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	19	54.29	7304.1	4290.2	58.74	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*2*	35	10	28.57	6010.2	1478.1	24.59	> 20.00
Beams		22	22	100.00		-		> 30.00
Columns	*3*	35	4	11.43	3445.2	519.4	15.08	< 40.00
Beams		22	16	72.73		-		> 30.00

Table 3.67. LS Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	1	2.86	5526.0	103.4	1.87	< 20.00
Beams		31	20	64.52		-		> 30.00
Columns	*2*	35	1	2.86	4547.1	117.9	2.59	< 20.00
Beams		31	11	35.48		-		> 30.00
Columns	*3*	35	0	0	2606.5	0.0	0	< 30.00
Beams		31	3	9.68		-		< 40.00

Table 3.68. LS Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	0	0.00	5526.0	0	0	< 20.00
Beams		31	21	67.74		-		> 30.00
Columns	*2*	35	0	0.00	4547.1	0	0	< 20.00
Beams		31	11	35.48		-		> 30.00
Columns	*3*	35	0	0	2606.5	0	0	< 30.00
Beams		31	0	0.00		-		< 40.00

Table 3.69. LS Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	2	5.71	4869.4	1034.4	21.24	> 20.00
Beams		22	18	81.82		-		> 30.00
Columns	*2*	35	4	11.43	4006.8	448.0	11.18	< 20.00
Beams		22	19	86.36		-		> 30.00
Columns	*3*	35	1	2.86	2296.8	108.7	4.73	< 30.00
Beams		22	11	50.00		-		> 40.00

Table 3.70. LS Performance Status (10% in 50 Years) of Education Building-B with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	35	3	8.57	4869.4	1118.2	22.96	> 20.00
Beams		22	20	90.91		-		> 30.00
Columns	*2*	35	4	11.43	4006.8	458.5	11.44	< 20.00
Beams		22	19	86.36		-		> 30.00
Columns	*3*	35	0	0	2296.8	0	0.	< 30.00
Beams		22	11	50.00		-		> 40.00

Table 3.71. RU Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	0	0	19489.8	0	0	< 0.00
Beams		18	15	83.33		-		> 10.00
Columns	2	42	18	42.86	17279.3	12938.1	74.88	> 0.00
Beams		38	29	76.32		-		> 10.00
Columns	3	42	14	33.33	14220.0	3109.9	21.87	> 0.00
Beams		38	28	73.68		-		> 10.00
Columns	4	42	12	28.57	8243.2	2527.2	30.66	> 0.00
Beams		38	18	47.37		-		> 10.00

Table 3.72. RU Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	18	26.87	19489.8	23215.5	119.12	> 0.00
Beams		18	12	66.67		-		> 10.00
Columns	2	42	18	42.86	17279.3	12938.1	74.88	> 0.00
Beams		38	28	73.68		-		> 10.00
Columns	3	42	13	30.95	14220.0	3006.5	21.14	> 0.00
Beams		38	28	73.68		-		> 10.00
Columns	4	42	12	28.57	8243.2	2527.5	30.66	> 0.00
Beams		38	19	50.00		-		> 10.00

Table 3.73. RU Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	5	7.46	19489.8	18492.9	94.89	> 0.00
Beams		24	18	75.00		-		> 10.00
Columns	2	42	18	42.86	17279.3	12751.1	73.79	> 0.00
Beams		29	27	93.10		-		> 10.00
Columns	3	42	15	35.71	14220.0	3141.8	22.09	> 0.00
Beams		29	29	100.00		-		> 10.00
Columns	4	42	17	40.48	8243.2	3561.4	43.20	> 0.00
Beams		29	27	93.10		-		> 10.00

Table 3.74. RU Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	5	7.46	19489.8	18492.9	94.89	> 0.00
Beams		24	18	75.00		-		> 10.00
Columns	*2*	42	20	47.62	17279.3	13038.2	75.46	> 0.00
Beams		29	26	89.66		-		> 10.00
Columns	*3*	42	20	47.62	14220.0	4996.0	35.13	> 0.00
Beams		29	27	93.10		-		> 10.00
Columns	*4*	42	20	47.62	8243.2	4114.2	49.91	> 0.00
Beams		29	26	89.66		-		> 10.00

Table 3.75. LS Performance Status (2% in 50 Years) of Education Building-C with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	28129.5	0	0	< 20.00
Beams		18	12	66.67		-		> 30.00
Columns	*2*	42	16	38.10	25918.9	19097.4	73.68	> 20.00
Beams		38	29	76.32		-		> 30.00
Columns	*3*	42	11	26.19	21330.0	4185.0	19.62	< 20.00
Beams		38	27	71.05		-		> 30.00
Columns	*4*	42	6	14.29	12364.9	2956.7	23.91	< 40.00
Beams		38	18	47.37		-		> 30.00

Table 3.76. LS Performance Status (2% in 50 Years) of Education Building-C with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	28129.5	0	0	< 20.00
Beams		18	10	55.56		-		> 30.00
Columns	*2*	42	15	35.71	25918.9	18073.7	69.73	> 20.00
Beams		38	28	73.68		-		> 30.00
Columns	*3*	42	11	26.19	21330.0	4184.4	19.62	< 20.00
Beams		38	27	71.05		-		> 30.00
Columns	*4*	42	6	14.29	12364.9	2956.7	23.91	< 40.00
Beams		38	19	50.00		-		> 30.00

Table 3.77. LS Performance Status (2% in 50 Years) of Education Building-C with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	4	5.97	28129.5	24647.3	87.62	> 20.00
Beams		24	17	70.83		-		> 30.00
Columns	2	42	14	33.33	25918.9	18433.7	71.12	> 20.00
Beams		29	27	93.10		-		> 30.00
Columns	3	42	12	28.57	21330.0	3694.9	17.32	< 20.00
Beams		29	28	96.55		-		> 30.00
Columns	4	42	15	35.71	12364.9	4660.3	37.69	< 40.00
Beams		29	27	93.10		-		> 30.00

Table 3.78. LS Performance Status (2% in 50 Years) of Education Building-C with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	4	5.97	28129.5	24647.3	87.62	> 20.00
Beams		24	17	70.83		-		> 30.00
Columns	2	42	18	42.86	25918.9	18705.9	72.17	> 20.00
Beams		29	26	89.66		-		> 30.00
Columns	3	42	10	23.81	21330.0	2936.6	13.77	< 20.00
Beams		29	27	93.10		-		> 30.00
Columns	4	42	15	35.71	12364.9	4775.0	38.62	< 40.00
Beams		29	25	86.21		-		> 30.00

Table 3.79. LS Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	1	67	0	0	19489.8	0	0	< 20.00
Beams		18	1	5.56		-		< 30.00
Columns	2	42	5	11.90	17279.3	1651.1	9.56	< 20.00
Beams		38	17	44.74		-		> 30.00
Columns	3	42	5	11.90	14220.0	1892.7	13.31	< 20.00
Beams		38	16	42.11		-		> 30.00
Columns	4	42	4	9.52	8243.2	1393.6	16.91	< 40.00
Beams		38	8	21.05		-		< 30.00

Table 3.80. LS Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	19489.8	0	0	< 20.00
Beams		18	1	5.56		-		< 30.00
Columns	*2*	42	6	14.29	17279.3	1931.0	11.18	< 20.00
Beams		38	17	44.74		-		> 30.00
Columns	*3*	42	5	11.90	14220.0	1892.7	13.31	< 20.00
Beams		38	15	39.47		-		> 30.00
Columns	*4*	42	3	7.14	8243.2	1058.4	12.84	< 40.00
Beams		38	8	21.05		-		< 30.00

Table 3.81. LS Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	3	4.48	19489.8	13948.3	71.57	> 20.00
Beams		24	0	0		-		< 30.00
Columns	*2*	42	4	9.52	17279.3	8096.2	46.85	> 20.00
Beams		29	17	58.62		-		> 30.00
Columns	*3*	42	1	2.38	14220.0	151.0	1.06	< 20.00
Beams		29	25	86.21		-		> 30.00
Columns	*4*	42	5	11.90	8243.2	788.4	9.56	< 40.00
Beams		29	11	37.93		-		> 30.00

Table 3.82. LS Performance Status (10% in 50 Years) of Education Building-C with TEC Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	3	4.48	19489.8	13948.3	71.57	> 20.00
Beams		24	0	0		-		< 30.00
Columns	*2*	42	4	9.52	17279.3	8096.2	46.85	> 20.00
Beams		29	20	68.97		-		> 30.00
Columns	*3*	42	1	2.38	14220.0	151.0	1.06	< 20.00
Beams		29	22	75.86		-		> 30.00
Columns	*4*	42	2	4.76	8243.2	274.0	3.32	< 40.00
Beams		29	15	51.72		-		> 30.00

Table 3.83. RU Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10748.5	0	0	< 0.00
Beams		18	2	11.11		-		> 10.00
Columns	*2*	42	0	0	8538.0	0	0	< 0.00
Beams		38	18	47.37		-		> 10.00
Columns	*3*	42	0	0	7026.3	0	0	< 0.00
Beams		38	18	47.37		-		> 10.00
Columns	*4*	42	0	0	4073.1	0	0	< 0.00
Beams		38	11	28.95		-		> 10.00

Table 3.84. RU Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10748.5	0	0	< 0.00
Beams		18	2	11.11		-		> 10.00
Columns	*2*	42	0	0	8538.0	0	0	< 0.00
Beams		38	18	47.37		-		> 10.00
Columns	*3*	42	0	0	7026.3	0	0	< 0.00
Beams		38	18	47.37		-		> 10.00
Columns	*4*	42	0	0	4073.1	0	0	< 0.00
Beams		38	10	26.32		-		> 10.00

Table 3.85. RU Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	3	4.48	10495.5	0	0	< 0.00
Beams		24	4	16.67		-		> 10.00
Columns	*2*	42	4	9.52	8284.9	0	0	< 0.00
Beams		29	24	82.76		-		> 10.00
Columns	*3*	42	0	0	6818.1	0	0	< 0.00
Beams		29	26	89.66		-		> 10.00
Columns	*4*	42	1	2.38	3952.4	0	0	< 0.00
Beams		29	17	58.62		-		> 10.00

Table 3.86. RU Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	4	5.97	10495.5	8906.4	84.86	> 0.00
Beams		24	9	37.50		-		> 10.00
Columns	*2*	42	4	9.52	8284.9	3906.7	47.15	> 0.00
Beams		29	23	79.31		-		> 10.00
Columns	*3*	42	0	0	6818.1	0.0	0	< 0.00
Beams		29	25	86.21		-		> 10.00
Columns	*4*	42	1	2.38	3952.4	70.5	1.78	> 0.00
Beams		29	19	65.52		-		> 10.00

Table 3.87. LS Performance Status (2% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	15017.5	0	0	< 20.00
Beams		18	1	5.56		-		< 30.00
Columns	*2*	42	0	0	12807.0	0	0	< 20.00
Beams		38	17	44.74		-		> 30.00
Columns	*3*	42	0	0	10539.5	0	0	< 20.00
Beams		38	18	47.37		-		> 30.00
Columns	*4*	42	0	0	6109.7	0	0	< 40.00
Beams		38	10	26.32		-		< 30.00

Table 3.88. LS Performance Status (2% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	15017.5	0	0	< 20.00
Beams		18	2	11.11		-		< 30.00
Columns	*2*	42	0	0	12807.0	0	0	< 20.00
Beams		38	15	39.47		-		> 30.00
Columns	*3*	42	0	0	10539.5	0	0	< 20.00
Beams		38	13	34.21		-		> 30.00
Columns	*4*	42	0	0	6109.7	0	0	< 40.00
Beams		38	10	26.32		-		< 30.00

Table 3.89. LS Performance Status (2% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	1	1.49	14638.0	4208	28.75	> 20.00
Beams		24	4	16.67		-		< 30.00
Columns	*2*	42	4	9.52	12427.4	5836	46.96	> 20.00
Beams		29	23	79.31		-		> 30.00
Columns	*3*	42	0	0	10227.2	0	0	< 20.00
Beams		29	25	86.21		-		> 30.00
Columns	*4*	42	0	0	5928.6	0	0	< 40.00
Beams		29	16	55.17		-		> 30.00

Table 3.90. LS Performance Status (2% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	1	1.49	14638.0	4208	28.75	> 20.00
Beams		24	6	25.00		-		< 30.00
Columns	*2*	42	4	9.52	12427.4	5836	46.96	> 20.00
Beams		29	22	75.86		-		> 30.00
Columns	*3*	42	0	0	10227.2	0	0	< 20.00
Beams		29	23	79.31		-		> 30.00
Columns	*4*	42	0	0	5928.6	0	0	< 40.00
Beams		29	17	58.62		-		> 30.00

Table 3.91. LS Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10748.5	0	0	< 20.00
Beams		18	0	0		-		< 30.00
Columns	*2*	42	0	0	8538.0	0	0	< 20.00
Beams		38	2	5.26		-		< 30.00
Columns	*3*	42	0	0	7026.3	0	0	< 20.00
Beams		38	2	5.26		-		< 30.00
Columns	*4*	42	0	0	4073.1	0	0	< 40.00
Beams		38	0	0.00		-		< 30.00

Table 3.92. LS Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for X- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10748.5	0	0	< 20.00
Beams		18	0	0		-		< 30.00
Columns	*2*	42	0	0	8538.0	0	0	< 20.00
Beams		38	2	5.26		-		< 30.00
Columns	*3*	42	0	0	7026.3	0	0	< 20.00
Beams		38	1	2.63		-		< 30.00
Columns	*4*	42	0	0	4073.1	0	0	< 40.00
Beams		38	0	0		-		< 30.00

Table 3.93. LS Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y+ Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10495.5	0	0	< 20.00
Beams		24	0	0		-		< 30.00
Columns	*2*	42	1	2.38	8284.9	1111.63	13.42	< 20.00
Beams		29	0	0		-		< 30.00
Columns	*3*	42	0	0	6818.1	0	0	< 20.00
Beams		29	2	6.90		-		< 30.00
Columns	*4*	42	0	0	3952.4	0	0	< 40.00
Beams		29	0	0		-		< 30.00

Table 3.94. LS Performance Status (10% in 50 Years) of Education Building-C with Site-Specific Design Spectrum for Y- Direction

Str. Elements	Floor	Total Str. Elements	Failed Str. Elements	% of Failed Str. Elements	V_{total} (kN)	V_{failed} (kN)	% of V_{failed}	Limit
Columns	*1*	67	0	0	10495.5	0	0	< 20.00
Beams		24	0	0		-		< 30.00
Columns	*2*	42	1	2.38	8284.9	1111.63	13.42	< 20.00
Beams		29	2	6.90		-		< 30.00
Columns	*3*	42	0	0	6818.1	0	0	< 20.00
Beams		29	6	20.69		-		< 30.00
Columns	*4*	42	0	0	3952.4	0	0	< 40.00
Beams		29	0	0		-		< 30.00

Table 3.95. Performance Status of Education Buildings

		RU (10% in 50 Years)	LS (2% in 50 Years)	LS (10% in 50 Years)
Education Building-A	**TEC**	X	X	X
	SSDS	√	√	√
Education Building-B	**TEC**	X	X	X
	SSDS	X	X	X
Education Building-C	**TEC**	X	X	X
	SSDS	X	X	√

4. CONCLUSIONS

In this study, local ground conditions and the suitability of existing conditions of some education buildings designed according to TEC-1975 with linear elastic analysis method were investigated. In addition, site-specific design spectra were formed with local ground conditions to compare the effects of different spectra.

Purpose of use of the buildings is school, so they are aimed RU performance level in an earthquake with probability of exceeding 10% in 50 years, and LS performance level in an earthquake with probability of exceeding 2% in 50 years. Additionally, another performance level LS was considered for economic purposes with probability of exceeding 10% in 50 years. If the performance level of an education building meets this criterion, then strengthening works can be postponed for this education building.

Site-specific design spectrum and TEC design spectrum were used along with equivalent seismic load method for evaluation of earthquake performance of the education buildings. Results of the performance evaluation of the buildings by the equivalent seismic load method according to TEC-2007 are below the limit of the relative storey drifts for both LS and RU performance levels.

On the other hand, as a result of linear analysis by equivalent seismic load method, there are columns, shear walls, and beams in advanced damage zone on earthquake directions for all education buildings according to TEC design spectrum. Also, with the majority of the columns and beams on the 1^{st} and 2^{nd} floors exceeding the minimum damage zone in the two directions and even crossed the Collapse Zone, both methods have led to the failure to achieve LS (2% in 50 Years) and RU (10% in 50 Years) performance levels for education buildings B and C, so in its present condition for education buildings B and C, it does not satisfy TEC-2007.

In this context, main factors in failure of education buildings to achieve specified performances are:

- Most of the columns and beams are at ADZ. Also, 1^{st} and 2^{nd} storeys have higher V_d ratio due to contribution of shear walls than described in section 2.4 of this thesis in education building-A for RU and LS performance levels based on all earthquake directions of TEC design spectrum.

- Almost all the columns, beams are at ADZ and V_d ratios in all storeys are higher than desired value in education building-B for RU and LS performance levels based on all earthquake directions of TEC design spectrum.
- Most of the beams are at ADZ in education building-B for RU and LS performance levels based on all earthquake directions of SSDS .
- Some of the columns, beams are at ADZ and V_d ratios in last two storeys are higher than desired value in education building-C for RU and LS performance levels based on all earthquake directions of TEC design spectrum.
- 30% of the beams are at SDZ in in education building-C for RU performance levels based on all earthquake directions of SSDS.

In addition, education building-A does not satisfy TEC-2007 either. When analyses are repeated using SSDS, education building-B is still not satisfactory at all. On the other hand, education building-A satisfies all the performance criteria. Education building-C is only satisfactory for LS (10% in 50 Years) condition. If one follows TEC-2007, all three buildings need strengthening works right away. However, using the available information, the following administrative decisions can also be made:

- Education building-B needs strengthening as soon as possible.
- Education building-A needs strengthening but can be postponed to a much longer time for strengthening works.
- Education building-C also needs strengthening; it is the first building to be strengthened after urgent education buildings are completed.

Lastly, considering the extra effort and time for SSDS, these preliminary results may not be applicable and satisfactory to adopt SSDS at buildings constructed conforming to old TEC regulations. However, when economic reasons are considered, SSDS provide efficient results than TEC-2007 design spectrum.

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LIST OF APPENDICES

Appendix A. Drilling Works and Their Samples

Figure A.1. Drilling Works and Their Samples for Education Building-A

Figure A.2. Drilling Works and Their Samples for Education Building-B

Figure A.3. Drilling Works and Their Samples for Education Building-C

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