DOI:10.22337/2587-9618-2024-20-3-125-144

RC BUILDINGS RESPONSE TO EARTHQUAKES: NONLINEAR STATIC ANALYSIS CONSIDERING VARYING SOIL TYPES AND SEISMIC CODES

Amer Yassin [1]***, Rifat Resatoglu*** [2]

[1] Department of Civil Engineering, Faculty of Civil and Environmental Engineering, Nicosia, NORTHERN CYPRUS
[2] Department of Civil Engineering, Faculty of Civil and Environmental Engineering, Nicosia, NORTHERN CYPRUS

Abstract: Reinforced concrete (RC) building construction remains predominant in Northern Cyprus, offering resilience against natural disasters when appropriately designed and implemented. This paper presents a seismic analysis of RC building systems across different stories, configurations, and soil classes, according to three seismic design codes: The Northern Cyprus Seismic Code 2015 (NCSC-2015), Eurocode 8 (EC 8), and Turkish Buildings Earthquake Code 2018 (TBEC-2018). The study compares regular and irregular forms of Moment Resisting Frame (MRF) and MRF combined with Shear Walls (MRF+SW) systems in various configurations: G+3, G+7, and G+11 for regular buildings, and only G+11 for irregular buildings. Pushover analysis using ETABSv18 was employed to assess base shear, displacement, and plastic hinge behavior. The results indicate that structural regularity enhances resistance and longevity compared to irregular configurations, with shear walls augmenting resistance against earthquake loads in both regular and irregular buildings. Furthermore, soil class emerges as a significant factor influencing results across the codes. While variations among the codes were not consistently observed, EC 8 and TBEC-2018 often appeared more conservative, with TBEC-2018 demonstrating greater adaptability to advanced technologies and a more detailed parameter consideration.

Keywords: Earthquake, Pushover analysis method, Reinforced concrete, Soil classes, Seismic codes, Northern Cyprus, ETABSv18

ОТКЛИК ЖЕЛЕЗОБЕТОННЫХ КАРКАСОВ ЗДАНИЙ ПРИ ЗЕМЛЕТРЯСЕНИЯХ: НЕЛИНЕЙНЫЙ СТАТИЧЕСКИЙ АНАЛИЗ С УЧЕТОМ РАЗЛИЧНЫХ ТИПОВ ГРУНТОВ И СЕЙСМИЧЕСКИХ НОРМ

Амер Ясин [1]***, Рифат Ресатоглу*** [2]

[1] Кафедра гражданского строительства, факультет гражданского и экологического строительства, г. Никосия, СЕВЕРНЫЙ КИПР
[2] Кафедра промышленного и гражданского строительства, факультет промышленного, гражданского и экологического строительства, г. Никосия, СЕВЕРНЫЙ КИПР

Аннотация: Железобетонные здания по-прежнему преобладают на Северном Кипре, поскольку они обладают устойчивостью к стихийным бедствиям при правильном проектировании и строительстве. В данной статье представлен расчет сейсмостойкости железобетонных несущих систем зданий различной этажности, конфигурации при различных категориях грунта в соответствии с тремя кодексами сейсмического проектирования: нормы сейсмостойкого строительства Северного Кипра 2015 года (NCSC-2015), Еврокод 8 (EC 8) и Турецкие нормы сейсмостойкого строительства 2018 года (TBEC-2018). В исследовании сравниваются регулярные и нерегулярные рамные каркасы с диафрагмами жесткости в различных конфигурациях: G+3, G+7 и G+11 для обычных зданий и G+11 для нерегулярных каркасов зданий. Для оценки сдвига основания, перемещений и работы пластических шарниров был применен pushover - анализ с использованием программного комплекса ETABSv18. Результаты показывают, что регулярность каркасов зданий повышает их устойчивость к воздействиям и долговечность по сравнению с нерегулярными конфигурациями каркасов. Диафрагмы жесткости повышают устойчивость к сейсмическим нагрузкам как в регулярных, так и в нерегулярных каркасах зданий. Кроме того, категория грунта является значимым фактором, влияющим на результаты расчета согласно всем рассмотренным кодексам проектирования. Хотя различия между кодексами не столь существенны, EC 8 и TBEC-2018 часто оказываются достаточно консервативными. При этом TBEC-2018 демонстрирует большую адаптируемость к передовым технологиям и более детальному рассмотрению параметров.

Ключевые слова: землетрясение, pushover анализ, железобетон, категории грунтов, сейсмические кодексы, Северный Кипр, ETABSv18

INTRODUCTION

Reinforced concrete structures are frequently seen worldwide due to the high capacity they can carry and the large number of floors they can consist of. Consequently, a comprehensive understanding of RC structure design is crucial, as failure in any component or joint can lead to catastrophic collapse, resulting in significant loss of life. Particularly, the consideration of earthquake loads in RC structure design has become paramount due to the substantial casualties often associated with seismic events. While it's impossible to guarantee complete safety during earthquakes, adherence to seismic code regulations can substantially enhance building safety. For instance, the recent earthquake in Turkey and Northern Syria on February 6th, 2023, measuring 7.7 magnitude and followed by a 7.6 magnitude aftershock with over 9000 subsequent tremors, highlighted the consequences of neglecting code requirements. The failure to comply with seismic codes led to outcomes surpassing initial expectations. In general, strict adherence to code regulations is imperative to ensure structural resilience. Furthermore, code standards must be periodically updated to facilitate earthquake-resistant building design. However, in the case of Turkish codes, the comprehensive update process can be lengthy (Aksoylu et al., 2020).

ETABS has garnered considerable recognition and undergone substantial evolution over a span exceeding three decades, as delineated by Mule et al. (2020). A plethora of prior scholarly investigations have directed their focus toward leveraging ETABS for conducting structural analyses. Furthermore, its amenability to accommodating various design codes has facilitated the seamless execution of analyses across diverse regulatory frameworks, owing to its comprehensive repository encompassing such codes.

Seismic activity poses a complex load on structures, necessitating precise analysis to predict structural response accurately (Kocer, 2021). This seismic movement is categorized into various grades based on intensity. The first grade represents low movement, typically resulting in minimal to no damage. The second grade signifies moderate movement, which may lead to some non-structural damage. Finally, the third grade denotes intensive movement, causing both structural and non-structural damage (Yassin & Sadeghi, 2023).

The focus of this study is Northern Cyprus, which shares a direct border with Southern Cyprus. Both regions exhibit similarities in geographical nature, soil type, and environmental factors. Additionally, they are situated amidst two fault lines stemming from the East Anatolian Fault line. Despite these similarities, Northern Cyprus and Southern Cyprus adhere to different earthquake regulations, utilize distinct design codes, and consider various designing parameters. Furthermore, Northern Cyprus imports certain materials from Turkey, aligned with TBEC-2018 standards. Despite existing studies comparing different earthquake codes, there is a scarcity of research pertaining to NCSC-2015. Thus, there is a compelling need to compare NCSC-2015, EC 8, and TBEC-2018, as they all play integral roles or indirectly influence the same geographical area.

In the context of structural design practices in Cyprus, the NCSC-2015 standard is predominantly applied within the jurisdiction of Northern Cyprus, albeit supplemented by the importation of construction materials from

Turkey, as inferred from references within TEC-2007. Conversely, the EC8 standard finds prevalence in Southern Cyprus. Despite this, there remains a notable absence of direct comparisons between these codes in existing literature. Existing research has shown significant differences and inconsistencies, highlighting the need for a thorough investigation across different factors like soil type, number of storeys, and geographical locations. Therefore, this study seeks to strengthen and expand on previous findings, improving the reliability and applicability of the conclusions drawn from the analysis.

The following are some previous studies:

A comparative study between two Seismic design codes EC8 and NCSC-2015 was carried out by Reşatoğlu & Hamed, 2019. The results of base shear for EC8 and NCSC-2015 were similar. Another study carried out by Aksoylu et al, 2020 compares TBEC-2018, ASCE 7-16, and TEC-2007 using the linear equivalent method to analyze buildings with a different number of stories. The results show that the maximum base shear force was achieved at TEC-2007 for buildings that consist of 3 and 5 stories, whereas the maximum base shear force was achieved at TBEC-2018 for buildings that consist of 7 and 9 stories.

A study conducted by Atmaca & Atmaca in 2019 pointed out that the TBEC-2018 introduces two new earthquake analysis methods, namely Nonlinear and Linear, which were not present in TEC-2007. Moreover, TBEC-2018 offers several advantages, including specifying the earthquake site and the soil type with six classes instead of four. Additionally, it accounts for both long and short periods of acceleration coefficients. Ultimately, the study's findings indicate that the 2018 code is more cautious compared to the previous one.

In conclusion, Nicosia (Gonyeli region) and Yeni Iskele (Long Beach region) were selected in this study due to the population growth and the different soil type properties they have. For example, the Long Beach region has alluvial soil while some locations in southern Turkey that were affected by the 6th of February earthquake have the same soil. This soil type is listed as the softest soil type in the three codes, while it significantly amplifies the shaking of the ground during earthquakes (Büyüksaraç et al, 2014).

The primary aim of this study is to compare the analysis outcomes of NCSC-2015, EC 8, and TBEC-2018, with the following objectives:

1. Conducting seismic analysis through nonlinear static analysis (Push Over) of both three-dimensional (3D) regular and irregular moment-resisting frame (MRF) systems, as well as regular and irregular moment-resisting frame with shear walls (MRF+SW) systems using ETABSv18 Software.
2. Comparing the resulting base shear and displacement values obtained from the analysis.
3. Observing the formation of plastic hinges to identify the weakest joints within the building structures.

SEISMICITY OF CYPRUS

The predicted period for the return of a rock condition earthquake is estimated to be 475 years. The studied area, Cyprus, is surrounded by three tectonic plates: the Anatolian plate moving westward, the African plate moving northward, and the Arabian plate moving northward at a faster pace. These plates are interconnected by fault lines, including the East Anatolian fault line, which has two extension fault lines traversing through the island. Previous studies, such as those by Cagnan et al. (2010), have suggested that the East Anatolian Fault has active extensions both to the south and north of Cyprus. These fault lines span across several countries, including Turkey, Syria, Cyprus, Lebanon, Palestine, and Jordan, as depicted in Figure 1.

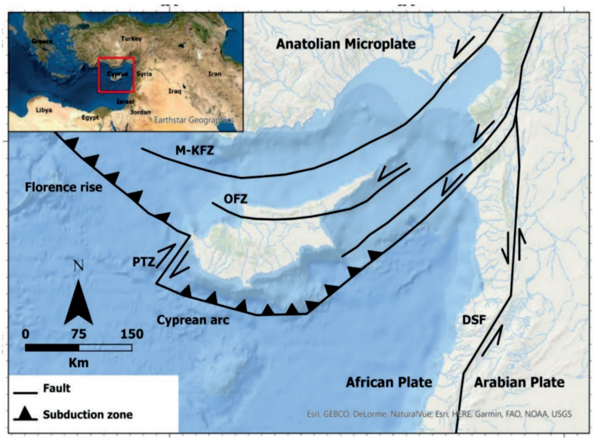


Figure 1. The Fault Lines Between the Anatolian Plate, Arabian Plate, and African Plate (Evelpidou. 2022)

SESMIC DESIGN CODES

Codes serve as the foundation of design regulations, providing engineers with essential guidelines for their calculations. It is crucial for codes to undergo continuous study and updating over time to ensure they evolve and remain relevant. In the realm of civil engineering, earthquake codes have been established for quite some time. In Turkey, for instance, earthquake codes date back to as early as 1940, with the most recent version being in 2018, marking the 10th iteration (Işık, 2021).

NCSC-2015 and EC8 have a seismic zone map that shows different areas based on earthquake severity, where each area has a specific peak ground acceleration (PGA). The map is divided into four seismic zones according to NCSC-2015 and three seismic zones according to EC8, where the selected locations in this study are located in the first zone in NCSC-2015 and the second zone in EC8 as shown in Fig 2 and Fig 3.

The TBEC-2018 introduces changes in the process compared to NCSC-2015 and EC8. Instead of PGA values, it now employs short-period spectral acceleration (Ss) and long-period spectral acceleration (S1). Furthermore, it's the first code to incorporate horizontal and vertical design spectra, appearing to be better aligned with modern technologies. It's launched with more detailed information for each province in Turkey. Unfortunately, this code and its map are specific to Turkey, but the approach can be adapted and applied to other codes in different regions.

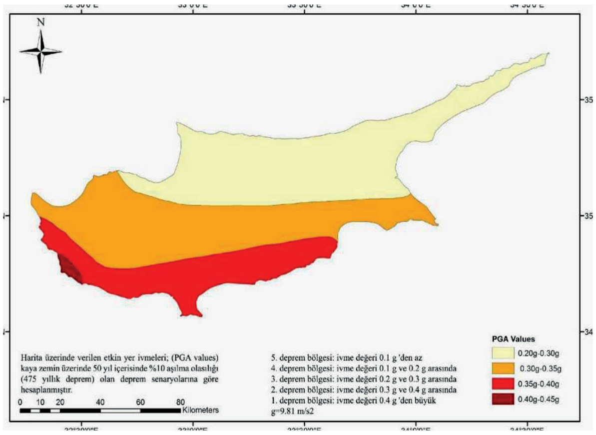


Figure 2. Seismic Zoning Map of Cyprus According to NCSC-2015 (NCSC-2015)

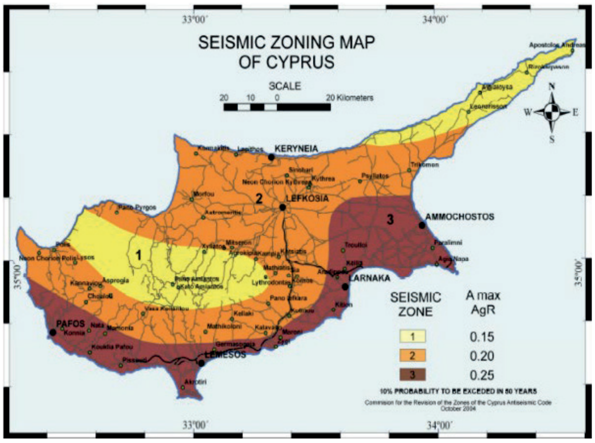


Figure 3. Seismic Zoning Map of Cyprus According to EC8 (Cyprus National Annex, Eurocode 8)

To conclude, numerous new concepts have been added in TBEC-2018 such as the classification of building height, earthquake ground motion level, vertical elastic design spectrum, earthquake design class, and the application of earthquake hazard on a regional basis was the most important addition to this code (Büyüksaraç, 2022).

In order to obtain the ratio of spectral acceleration to PGA check Fig 4, which represents the ratio between spectral acceleration and PGA of return periods ranging from 100 to 1000 years from the database of more than 50 studies. (Lubkowski & Aluisi, 2012).

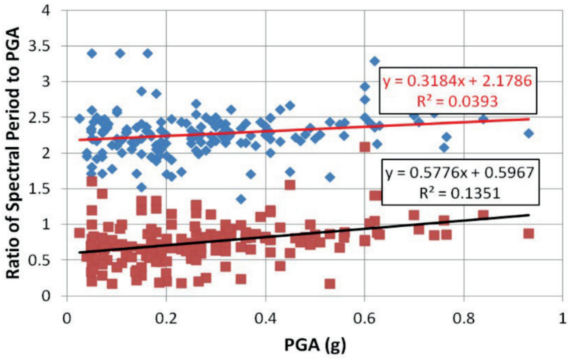


Figure 4. The Ratio of Spectral Period to PGA from Seismic Hazard Database (Lubkowski & Aluisi, 2012)

Blue diamonds represent the ratio between Ss and PGA, and therefore, by identifying the PGA, Ss can be obtained from this equation:

SS/PGA= 0.3386 PGA + 2.1696

On the other hand, red squares represent the ratio between S1 and PGA, and therefore, by identifying the PGA, S1 can be obtained from this equation:

S1/PGA= 0.5776 PGA + 0.5967

NONLINEAR STATIC ANALYSIS

The pushover analysis method is the method that aims to push the structure till it reaches the maximum resistance, and according to the applied earthquake properties such as PGA, soil type, spectral acceleration, etc, the building has two possibilities:

1. If a building reaches a collapsed state, therefore, this building is unsafe, and the applied earthquake loads have pushed the structure till it collapses.
2. If a building reaches its maximum limit without collapsing during an earthquake, it means that the structure has endured the maximum earthquake loads without showing any critical hinges. This indicates that the building is considerably safe and that the applied earthquake loads have pushed the structure to a specific limit.

This method evaluates the real strength and structure seismic performance. Therefore, after running the pushover analysis, the base shear and displacement curve can be obtained, this curve shows the start point and the maximum point that the structure has reached whether it collapsed after this point or not as shown in Fig 5.

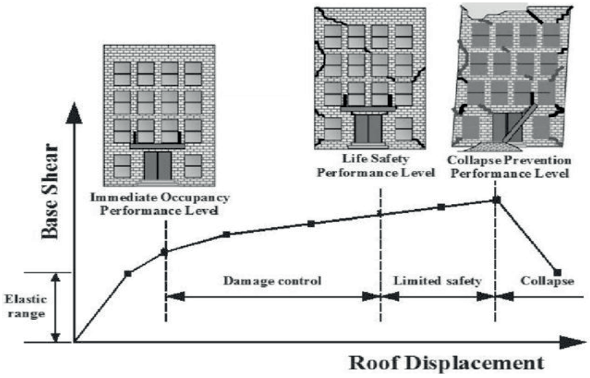


Figure 5. Capacity Curve of Structures with Demonstration of Damage State and Building Performance Level (Abd-Elhamed & Mahmoud, 2016)

The previous figure describes the seismic performance of a building during an earthquake in four steps Operational, Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP), respectively, and each step has a worse state compared to the previous step.

METHODOLOGY

Several case studies were analyzed according to these three earthquake regulations NCSC-2015, EC 8, and TBEC-2018, targeting to obtain different outcomes for strengthening the comparative study.

In this study, regular and irregular floorplan structures have been selected with specific details. For example, the ground story height is 3.2 m, whereas the remaining stories' heights are 3 m. The beams and columns were modelled as frame elements, whereas solid slabs and shear walls were modelled as shell elements. Additionally, Plastic hinges were added at 10% and 90% of the length of each column and beam, to achieve more accurate results while applying the pushover analysis method and observing plastic hinges occurrence, which is practical to predict the first member to fail.

The modeling of foundations was intentionally omitted from the scope of this study and was simply treated as fixed within the software to streamline and expedite the process, given the large number of buildings being modeled. The primary objective of the study is to compare the outcomes of different codes and determine the most effective one for future studies. Consequently, this assumption was uniformly applied across all selected models. However, it is important to note that the results could be influenced and altered if alternative foundation types were utilized. In a 2015 study by Somwanshi and Pantawane, it was revealed that buildings with fixed bases exhibit no displacement at their base, whereas those with base isolation exhibit discernible displacement. This implies that the application of this assumption to all models could uniformly impact the results of each model.

The ETABS models were executed following a systematic procedure:

1. Material properties were selected.
2. Cross-sections for columns, beams, shear walls, and slabs were added.
3. Models were drawn.
4. Pattern loads including dead load, super dead load, live load, wind load, and earthquake load were incorporated.
5. Loads were applied to the members, excluding earthquake loads.
6. Plastic hinges were defined at the corners.
7. Nonlinear Static (pushover) load cases were addressed as follows:

A. The first load case considered dead load only.

B. The second load case considered super dead load with a scale factor of 1 and live load with a scale factor of 0.25. This case initiated after the completion of the first load case.

C. The third load case considered earthquake acceleration for both x and y directions with a scale factor of -1. Additionally, this case commenced after the second load case, and P-Delta effects were considered.

8. The analysis was executed.

P-Delta effect occurs when horizontal earthquake loads induce drift on structural elements, resulting in an eccentricity of the gravity loads along the vertical column axis. This induced eccentricity amplifies internal moments, consequently influencing the first-order moment (Istiono et al., 2022), as depicted in Figure 6.

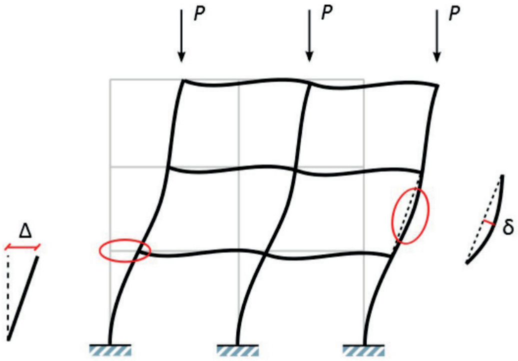


Figure 6. P-Large Delta (P-Δ) & P-Small Delta (P-δ)

In this study, the analyzed models consist of two systems: the Moment Resisting Frame (MRF) system and the combination of MRF with Shear Walls (MRF+SW) system. These systems were assessed with a shear wall span length of 1.5 meters in regular form for low, mid, and high-rise buildings. Additionally, irregular forms were considered solely for high-rise structures. Moreover, to ensure a robust comparison, the member sizes were kept consistent across all structures within each story for all three selected codes. Furthermore, two locations were selected: Yeni Iskele (Long Beach region) and

Nicosia (Gönyeli region). These locations exhibit distinct soil characteristics, as detailed in Tables 2, 3, and 4. Ground surveys aimed at earthquake resilience in the country reveal that the Long Beach region's coastal area has the lowest bearing capacity and is susceptible to liquefaction (Selcukhan & Ekinci, 2023). This region is characterized by soft alluvial soil, classified as class D in NCSC-2015 and class E in EC8 and TBEC-2018. Conversely, Nicosia city's soil varies, with the north featuring rocky medium soil, the center consisting of soft rock or very dense soil, and the south comprising solidified soil groups (Dindar, 2021). The Göneyli region, located in Nicosia, is characterized by stiff soil, classified as class C across all codes. Despite these differences, both locations were chosen due to their notable population growth and urbanization trends, as depicted in Figure 7.

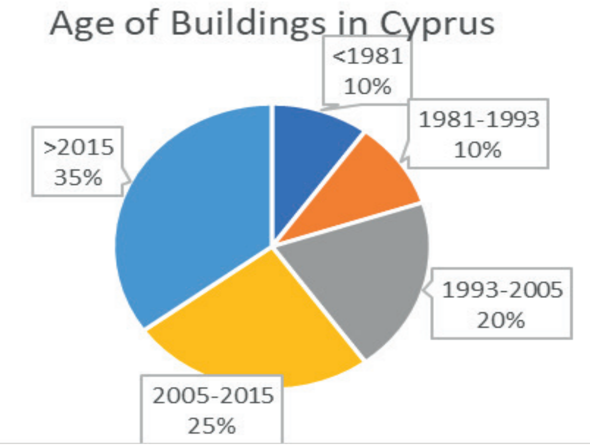


Figure 7. Buildings Age in Northern Cyprus (Earthquake committee meetings of the presidency of TRNC)

A. Regular Structures

These structures should be symmetrical in principle direction and have no significant discontinuity in plan or lateral configurations. In addition, members must continuously run from the highest point to the foundation without interruptions (Yadav & Hazari, 2022). Additionally, the structure can be described as having continuities in both plan and vertical configurations (Naveen et al., 2019). For this study, a regular typical plan was chosen, representing a residential building with three different story configurations: G+3, G+7, and G+11. These configurations have dimensions of 25 meters on the X axis and 25 meters on the Y axis, comprising five bays with a 5-meter bay length in each direction.

- Moment-Resisting Frame (MRF) in regular form as shown in Fig 8 and Fig 9.
- Moment-Resisting Frame with Shear Walls (MRF+SW) in regular form as shown in Fig 10 and Fig 11.

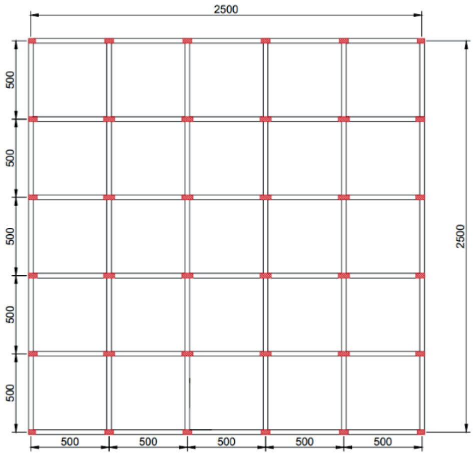
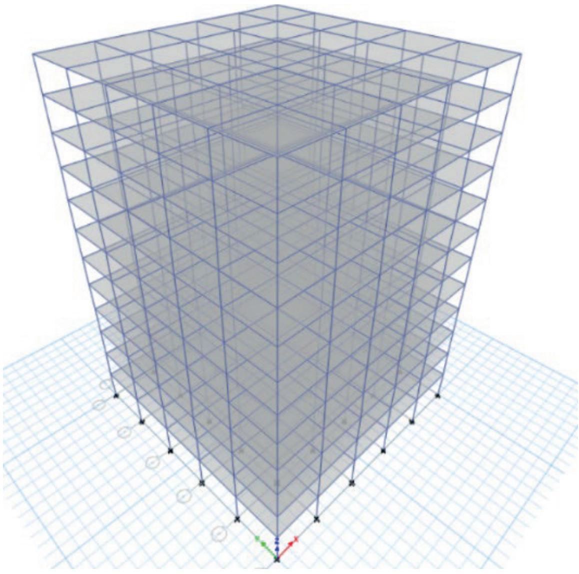
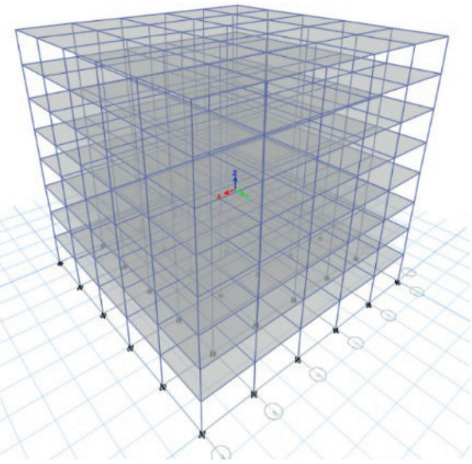


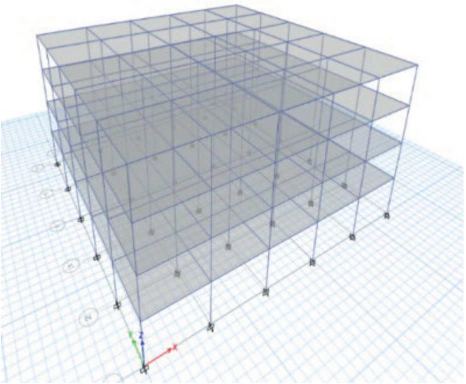
Figure 8. Floor plan for Moment-Resisting Frame (MRF) in Regular Form



a) G+11 stories



b) G+7 stories



c) G+3 stories

Figure 9. The 3D dimensional view for moment resisting frames (MRF) in regular form. a) G+11 Stories, b) G+7 Stories, c) G+3 Stories

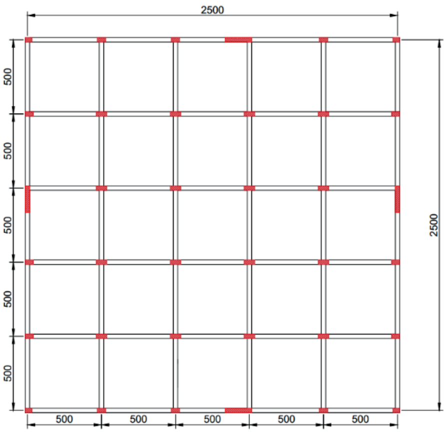
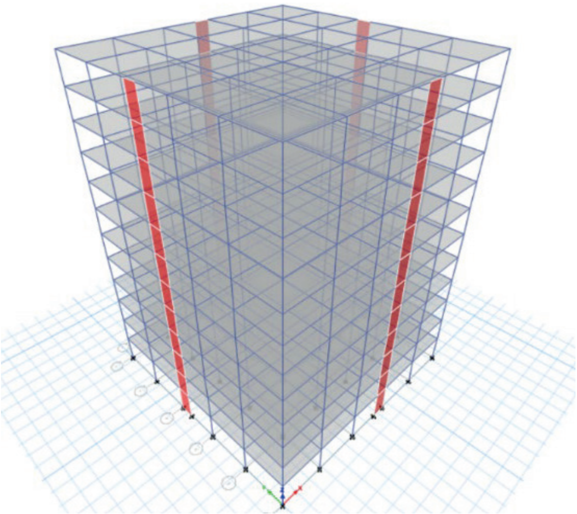
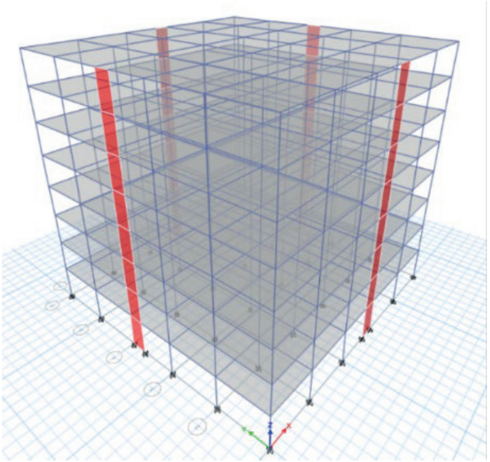


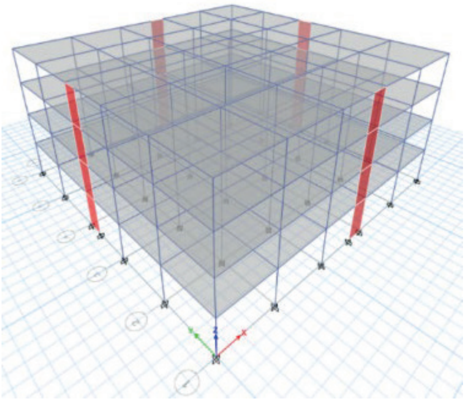
Figure 10. Floor Plan for Moment-Resisting Frame with shear walls (MRF+SW) in Regular Form



a) G+11 stories



b) G+7



c) G+8 stories

Figure 11. The 3D Dimensional View for (MRF+SW) in Regular Form a) G+3 Stories, b) G+7 Stories, c) G+11 Stories

B. Irregular Structures

These structures have a sudden physical discontinuity, either in plan, lateral configuration, or both, as they are kept unsymmetrical in the principal direction. (Yadav & Hazari, 2022). As a consequence, irregularity affects the structure's performance when it's subjected to seismic loads (Naveen et al, 2019). In simpler terms, irregular structures lack symmetry either in the X or Y coordinates, or both. Despite being recognized as weaker compared to regular structures in previous studies, they remain prevalent due to factors such as geographical constraints and other considerations. A residential building with an irregular plan was chosen for this study. It comprises eleven stories (G+11) and has dimensions of 25 meters on both the X and Y axes. The building features discontinuous five bays, each with a length of 5 meters.

- Moment-Resisting Frame (MRF) in irregular form as shown in Fig 12 and Fig 13.

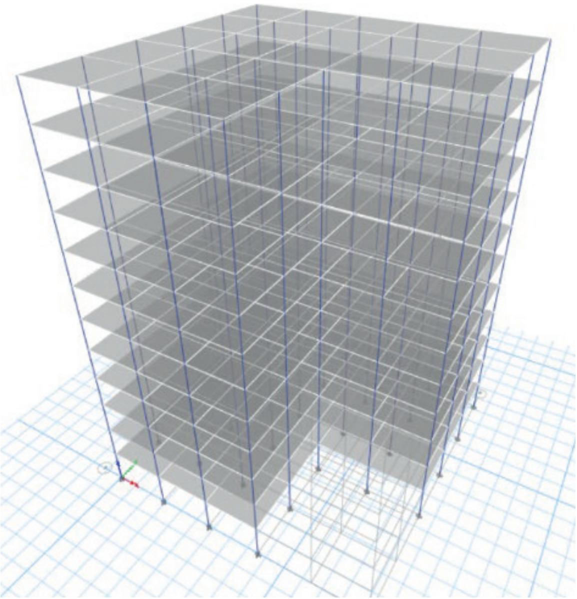


Figure 13. The 3D Dimensional View for (MRF) in Irregular Form

- Moment Resisting Frame with Shear walls (MRF+SW) in irregular form as shown in Fig 14 and Fig 15.

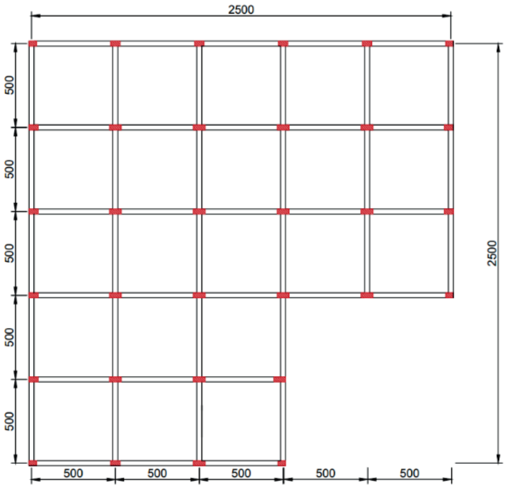


Figure 12. Floor Plan for Moment-Resisting Frame (MRF) in Irregular Form

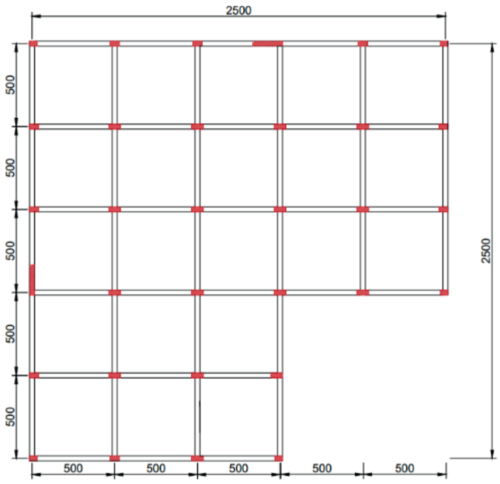


Figure 14. Floor Plan for (MRF+SW) in Irregular Form

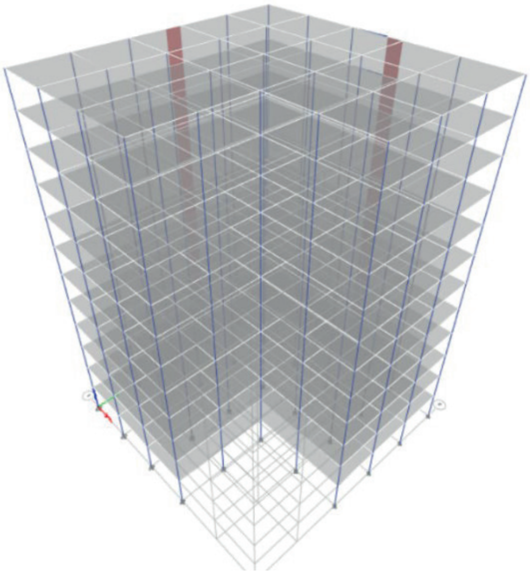


Figure 15. The 3D Dimensional View for (MRF+SW) in Irregular Form

DESIGN CRITERIA

48 models were analyzed by applying the nonlinear static analysis (Pushover Analysis) using ETABSv18 software. Furthermore, the same material properties and loads were applied for all buildings, such as dead load, super dead load, and live load. On the other hand, earthquake loads were selected according to the parameters of each code. The design criteria are shown as follows.

A. Material Properties.

The materials selected for the study were chosen to meet the requirements of all three codes. For instance, the minimum concrete strength specified by NCSC-2015, EC8, and TBEC-2018 is C20, C20/25, and C25, respectively. Additionally, following the 1999 earthquakes, the Turkish Ready Mixed Concrete Association recommended the use of C30 concrete in earthquake-prone areas (Zengin et al., 2023). Therefore, for this study, C30 concrete, which possesses a compressive strength of 30 MPa, was selected, with other concrete parameters determined accordingly based on this strength grade. The codes have different reinforcement steel classes. NCSC-2015 contains three steel classes S220, S420, and S500, while EC8 and TBEC-2018 have different steel classes. However, the only common steel class among the codes is S420. Therefore, this study uses the S420 steel grade. For brick walls, the approach differs as they can be chosen based on the prevalent brick wall type in the region. Hence, an average value was selected for the unit weight of brick walls. The table below displays the chosen parameters for concrete, steel, and brick walls for the study:

Table 1. Material properties of steel, concrete and walls

Parameter	Value
Compressive Strength ($f'c$)	30 MPa
Unit weight of Concrete	$30\ kN/m^3$
Concrete Modulus of Elasticity	25743 MPa
Yield Stress (Fy)	420 MPa
Minimum Tensile Strength (Fu)	520 MPa
Unit weight of Steel	$78.5\ kN/m^3$
Steel Modulus of Elasticity	210000 MPa
Unit weight of Brick walls	$16\ kN/m^3$

B. Section Properties.

Regular and Irregular models were selected for the analyzed structures consisting of 180mm solid slabs, (250mm*500mm) beams, 250mm external clay brick walls, 200mm internal clay brick walls, 250mm shear walls, and columns ranging from (300mm*300mm) to (300mm*800mm) depending on the floor and the position of the column, for example, the columns at the top floor are the smallest, and their size increase gradually to the bottom floor. In addition, the corner columns are the smallest, and the size increases in the external columns, where the center columns are the biggest.

C. Load Properties.

The selected loads were considered according to the codes and unit weight of the materials as follows: live load (2kN/m2), Super Dead load (2.5 kN/m2), external walls (12 kN/m), internal walls (9.6 kN/m), where dead load and wind load considered from the software. In addition, earthquake loads were taken according to each code as shown in part D.

D. Seismic Properties.

Earthquake properties are considered according to the requirements of each code, and the selected locations that mentioned in this study. The properties are shown in the following tables:

Table 2. NCSC-2015 earthquake regulations for both selected locations in the study

Description		**Nicosia (Gönyeli region)**	**Yeni Iskele (Long beach region)**
Seismic Zone		1	1
Peak Ground acceleration (PGA)		0.3	0.3
Soil type		C	D
Behaviour factor (R)	**MRF**	8	8
	MRF+ SW	7	7
Importance factor (I)		1	1

Table 3. EC 8 earthquake regulations for both selected locations in the study

Description		**Nicosia (Gönyeli region)**	**Yeni Iskele (Long beach region)**
Seismic Zone		2	2
Peak Ground acceleration (PGA)		0.2	0.2
Soil type		C	E
Soil Factor		1.15	1.4
Importance factor (I)		1	1
Lower limit of the period (TB)		0.2	0.15
Upper limit of the period (TC)		0.6	0.5
The beginning of the constant displacement (TD)		2	2
Behaviour Factor q	**MRF**	5.85	5.85
	MRF +SW	5.4	5.4
Correction Factor		1	1

Table 4. TBEC-2018 earthquake regulations for both selected locations in the study

Description		**Nicosia (Gönyeli region)**	**Yeni Iskele (Long beach region)**
Spectral Acceleration for short period (Ss)		0.6795	0.6795
Spectral Acceleration for 1 second (S1)		0.2259	0.2259
Long-Period Transition Period		8	8
Site type		ZC	ZE
Response modification (R)	**MRF**	8	8
	MRF +SW	7	7
System overstrength (D)	**MRF**	3	3
	MRF +SW	2.5	2.5
Importance factor (I)		1	1

RESULTS AND DISCUSSION

In this part, all obtained results from the Non-linear Static Analysis method such as base shear, displacement, and plastic hinges occurrence were presented and explained as graphs and compared according to regular and irregular structures. The results were prepared in order of building type as follows:

1. MRF in Regular Form

The results such as base shear, displacement, and plastic hinges formation for MRF in regular form were obtained according to two soil types, three codes, and three different story structures with different numbers of stories.

A. Base Shear and Displacement.

The pushover curve that shows the base shear forces and displacement for MRF residential buildings in regular form with different number of stories, different codes, and soil classes are shown below in Fig 16 and Fig 17.

Based on the preceding graph charts, both NCSC-2015 and EC8 exhibited marginal increases, not exceeding 5%, in the soft soil class across all the models. In contrast, TBEC-2018 demonstrated an increase in the soft soil class for all models.

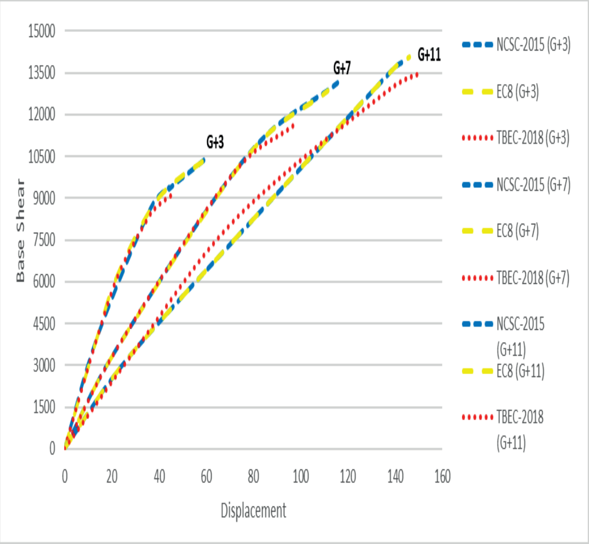


Figure 16. Pushover Curves for MRF structure in regular form, medium soil class

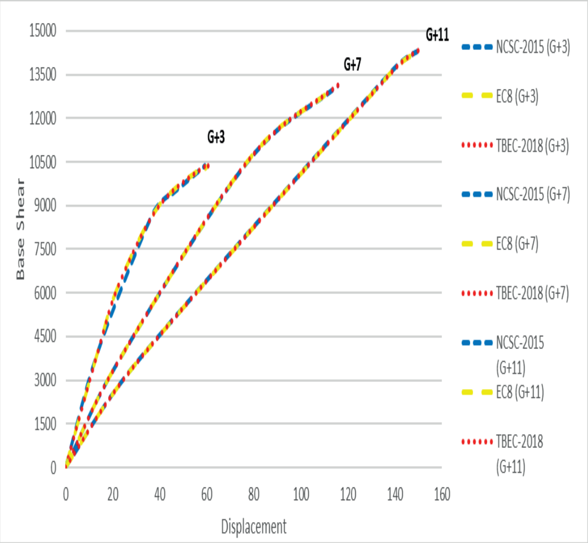


Figure 17. Pushover Curves for MRF structure in regular form, soft soil class

In TBEC-2018, there was a modest 6% increase in base shear for the G+11 model in the soft soil class. However, this increase escalated in the G+7 models, reaching 12% for base shear and 18% for displacement. Moreover, the G+3 models experienced a slight rise in the soft soil class, reaching 14% for base shear and 23% for displacement.

B. Plastic Hinges.

The presence of plastic hinges plays a critical role in determining the structural integrity of buildings during earthquakes. In many instances, plastic hinges were observed in various locations throughout the buildings, with some exceeding the critical plastic (CP) state, particularly in the ground and first stories. As a consequence, all those models in the selected areas are in danger and not lucky enough to stay standing during earthquakes.

C. Summary.

EC8 and NCSC-2015 exhibited only a slight disparity between medium and soft soil classes, whereas TBEC-2018 demonstrated a more significant and realistic discrepancy, with a notable increase in the soft soil class.

The regular MRF models appeared to be vulnerable in earthquake-prone areas, as indicated by the increase in base shear and displacement in soft soil class models.

Moreover, in some instances, these values remained comparable to those in medium soil class models.

Furthermore, the majority of plastic hinge occurrences, including the CP state, were concentrated in the first three stories. Consequently, these models appear to be at substantial risk, as failure in any of these plastic hinges could potentially result in the collapse of the entire structure in practice.

2. MRF+SW In Regular Form

The results such as base shear, displacement, and plastic hinges formation for MRF+SW in regular form were obtained according to two soil types, three codes, and three different story structures with different numbers of stories.

A. Base Shear and Displacement.

The pushover curve that shows the base shear forces and displacement for MRF+SW residential buildings in regular form with different number of stories, different codes, and soil classes are shown below in Fig 18 and Fig 19.

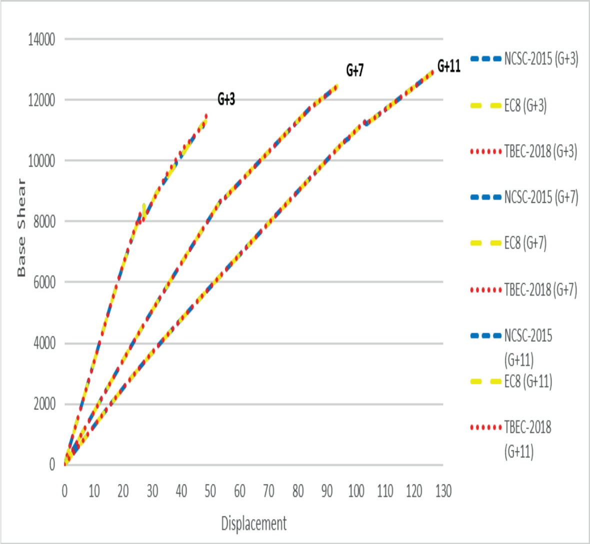


Figure 18. Pushover Curves for MRF+SW structures in regular form, medium soil class

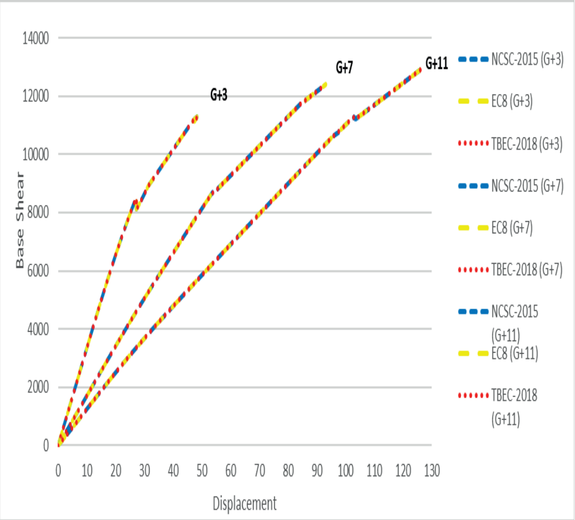


Figure 19. Pushover Curves for MRF+SW structures in regular form, soft soil class

The graph lines indicate that across all cases, there are relatively consistent results between medium and soft soil types. However, while the base shear shows a slight increase from G+3 to G+11, the displacement experiences a significant rise over the same range.

In NCSC-2015 and EC8 models, no notable distinctions were observed between medium and soft soil classes; their performances appeared similar.

Contrastingly, TBEC-2018 exhibited a slight decrease in base shear and displacement by approximately 5% in the soft soil class for G+3 models. Additionally, only one plastic hinge, reaching the critical plastic (CP) state, was identified in the G+3 soft soil class model. Consequently, this model may reach failure sooner than the corresponding medium soil class model, which could explain the observed decrease rather than an increase.

B. Plastic Hinges.

The occurrence of plastic hinges was consistent across all codes, with one plastic hinge reaching the critical plastic (CP) state in all G+3 models on the ground floor. Additionally, some plastic hinges with IO and LS states occurred in all G+7 and G+11 models on both the first and ground floors. Consequently, G+7 and G+11 configurations appeared to exhibit greater safety in this regard compared to G+3 configurations.

C. Summary.

NCSC-2015 and EC8 depicted no difference between medium and soft soil classes, while TBEC-2018 depicted a slight base shear decrease in the soft soil of G+3. Although the results showed only one difference, MRF+SW models seemed to perform better compared to MRF, especially in G+7 models and above.

3. MRF In Irregular Form

The results, including base shear, displacement, and plastic hinge formation, for irregular MRF configurations were obtained based on two soil types and three seismic design codes, specifically for high-rise buildings.

A. Base Shear and Displacement

The pushover curve that shows the base shear forces and displacement for high-rise MRF residential buildings in irregular form with different codes and different soil classes are shown below in Fig 20.

Figure 20. Pushover curves for MRF in an irregular form, medium and soft soil class

The preceding line graph reveals that the peak base shear and displacement were observed in NCSC-2015. However, there was no notable change in the results for EC8 and TBEC-2018. In NCSC-2015, both base shear and displacement increased by 10% and 17%, respectively, in the soft soil class. Consequently, models designed according to NCSC-2015 exhibited greater resilience and endured for a longer period before collapse compared to those designed according to other codes.

B. Plastic Hinges.

Plastic hinges reaching the critical plastic (CP) state were observed in all models. In NCSC-2015, these hinges appeared on the ground, first, and second floors for the soft soil class, while fewer hinges were observed in the medium soil class, appearing only on the ground and first floors.

Conversely, EC8 and TBEC-2018 did not exhibit a distinction between medium and soft soil classes. However, CP state plastic hinges were predominantly located on the ground and first floors.

C. Summary.

The models seemed unsafe in all cases, but in EC8 and TBEC-2018 the consideration of danger occurrence was higher and the collapse seemed to happen earlier than NCSC-2015.

The irregular MRF models appeared very weak and unable to resist earthquake loads.

4. MRF+SW in Irregular Form.

The results such as base shear, displacement, and plastic hinges formation for MRF+SW in irregular form were obtained according to two soil types, and three codes, and for only high-rise buildings.

A. Base Shear and Displacement.

The pushover curve that shows the base shear forces and displacement for high-rise MRF+SW residential buildings in irregular form with different codes and different soil classes are shown below in Fig 21.

The results depicted in this graph showed minimal variation among all models, with differences, if any, not exceeding 1%.

Primarily, the similarity in results can be attributed to the timing and location consistency of critical plastic hinge occurrences.

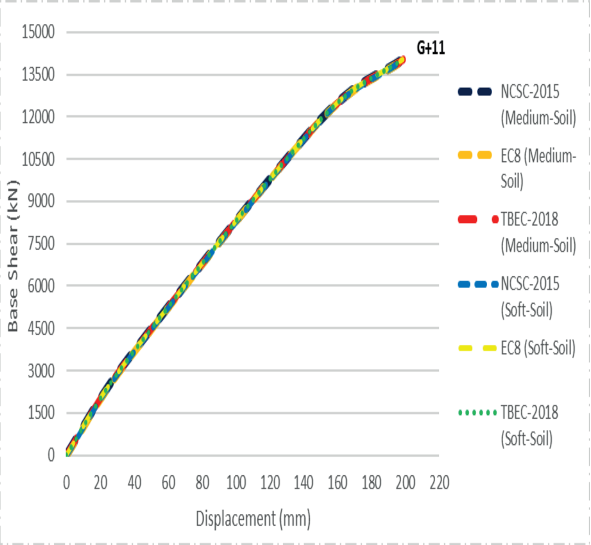


Figure 21. Pushover Curves for MRF+SW structures in an irregular form, medium and soft soil

B. Plastic Hinges.

All models faced plastic hinges occurrence with a CP state in the first three stories. Therefore, these structures appeared weak and couldn't resist the applied earthquake loads.

C. Summary.

The models displayed vulnerability and are unlikely to remain standing under the imposed earthquake conditions. Even though the 1.5 m span length shear walls may provide some resistance, it appeared to be insufficient.

Moreover, the simultaneous occurrence of critical plastic hinges at consistent locations suggests that the codes in this scenario predicted collapse at the same juncture.

CONCLUSION

1. MRF in the regular form:

The base shear and displacement exhibited an increase from G+3 to G+11 buildings. Particularly in TBEC-2018, the transition from medium to soft soil had a more realistic impact on base shear and displacement. However, across all structures, the presence of critical hinges indicated that they were unsafe.

2. MRF+SW in the regular form:

Base shear and displacement increased as the number of stories rose from G+3 to G+11 buildings. The results appeared consistent for both soil classes in all codes, except for TBEC-2018, which showed a slight decrease from medium to soft soil class for G+3 buildings. Overall, all structures seemed to remain stable and capable of withstanding the applied earthquake loads.

3. MRF in the irregular form:

In NCSC-2015, both base shear and displacement increased from medium to soft soil, while TBEC-2018 and EC 8 showed consistent results for both soil classes. However, TBEC-2018 and EC 8 predicted the occurrence of critical hinges earlier than NCSC-2015, suggesting that structures evaluated by NCSC-2015 may withstand more before collapsing. Nevertheless, all structures appeared unsafe due to the presence of critical hinges.

4. MRF+SW in the irregular form:

For all codes, base shear and displacement showed no variation between soil classes, and critical hinges occurred at identical locations. Consequently, all structures were deemed unsafe due to the presence of critical hinges.

5. Primary conclusions:

- The codes stated similar results when:

A. Structures are safe, and no plastic hinges appeared.

B. Structures are unsafe but did not collapse according to the applied seismic loads.

- Shear walls play a critical role in mitigating the impact of earthquake loads.
- Buildings with regular shapes are generally more resilient to earthquakes compared to buildings with irregular shapes.
- The first three stories of a building are typically the most critical, as plastic hinges tend to occur in them predominantly.
- The findings underscore the importance of soil class as a significant factor influencing the results across different seismic design codes.
- It has been observed that the earthquake impact did not significantly change between the old and new regulations. However, this outcome

may vary depending on buildings with diverse geometric characteristics and soil classes.

- NCSC-2015 divides the island into four seismic regions with corresponding peak ground acceleration values, irrespective of local site conditions. In contrast, TBEC-2018 introduces a revised approach by incorporating a seismic hazard map and offering site-specific data based on the building's coordinates.
- TBEC-2018 appears to be more comprehensive and adapted to advanced technologies, considering parameters in a more detailed manner.
- Based on the findings, variations among the codes were not always evident. However, EC 8 and TBEC-2018 tended to be more conservative most of the time.
- The most significant change in TBEC-2018 compared to NCSC-2015 is the implementation of the Earthquake Hazard Map. TBEC-2018 utilizes specific earthquake properties based on coordinates from this map, defining short-period and long-period spectral acceleration for each location. Therefore, it would be beneficial to develop a new map for Cyprus using the updated procedure introduced in TBEC-2018.
- Despite the codes not indicating significant differences in the results, TBEC-2018 appeared to show more logical results and predict the danger earlier as this code also considers more parameters and specific details. Therefore, this study can state that TBEC-2018 is the most appropriate code compared to NCSC-2015 and EC8.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed for future research:

1. Future studies should consider comparing seismic design codes while also incorporating specific types of foundations within the scope of the study, such as mat foundations or base-isolated foundations.
2. It would be beneficial to conduct additional studies focusing on various types of soil to further explore their impact on structural behavior under earthquake loads.
3. Utilizing 3D models that closely resemble real-world structures is recommended for future studies, despite potential challenges in comparison. Such models provide increased accuracy and realism.
4. Future research endeavors can explore the development of a new earthquake map for Cyprus, similar to the approach adopted in Turkey, with coordinates providing site-specific seismic hazard data.
5. Researchers are encouraged to carefully select a subset of models and analyze them using multiple seismic analysis methods. This approach can yield more robust and accurate results, enhancing the understanding of structural response to seismic events.

REFERENCES

1. **Abd-Elhamed, A., Mahmoud, S.** (2016). Nonlinear static analysis of reinforced concrete framed buildings - A case study on Cairo earthquake. Journal of Engineering Research, Vol 4, No 4.
2. **Abraham, N.M., & SD, A.K.** (2019). Analysis of irregular structures under earthquake loads. Procedia Structural Integrity, 14, 806-819. https://doi.org/10.1016/j.prostr.2019.07.059
3. **Aksoylu, C., Mobark, A., Hakan Arslan, M., & Hakkı Erkan, İ.** (2020). A comparative study on ASCE 7-16, TBEC-2018 and TEC-2007 for reinforced concrete buildings. Revista de la Construcción, 19(2), 282-305.
4. ASCE 7: American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures from ASCE 7: Minimum Design Loads for Buildings and Other Structures (resource.org)
5. **Asim, K.M., Moustafa, S.S., Niaz, I.A., Elawadi, E.A., Iqbal, T., & Martínez-**

Álvarez, F. (2020). Seismicity analysis and machine learning models for short-term low magnitude seismic activity predictions in Cyprus. Soil Dynamics and Earthquake Engineering, 130, 105932.

6. **Atmaca, N., Atmaca, A., & KILÇIK, S.** (2019). Comparison of 2018 and 2007 Turkish Earthquake Regulations. The International Journal of Energy and Engineering Sciences, 4(2), 19-25.
7. **Bhatt, C., & Bento, R.** (2014). A 3D pushover methodology for seismic assessment of plan asymmetric buildings. Earthq Spectra Earthq Eng Res Inst, 30(2), 683-703.
8. **Büyüksaraç, A., Işık, E., & Bektaş, Ö.** (2022). A comparative evaluation of earthquake code change on seismic parameter and structural analysis; a case of Turkey. Arabian Journal for Science and Engineering, 47(10), 12301-12321.
9. **Cagnan, Z., & Tanircan, G.B.** (2010). Seismic hazard assessment for Cyprus. Journal of Seismology, 14, 225-246. https://doi.org/10.1007/s10950-009-9163-1
10. Cyprus National Annex, Eurocode 8, Design of structures for earthquake resistance.
11. **Dindar, H., Akgün, M., Atalar, C., & Özdağ, Ö.C.** (2021). The assessment of local site effects and dynamic behaviour in Nicosia, Cyprus. G eofizika, 38(1), 61-80.
12. Earthquake.Zone, (2023), from https://earthquakes.zone/cyprus
13. **Elhadidy, M., Abdalzaher, M.S., & Gaber, H.** (2021). Up-to-date PSHA along the Gulf of Aqaba-Dead Sea transform fault. Soil Dynamics and Earthquake Engineering, 148, 106835. https://doi.org/10.1016/j.soildyn.2021.106835
14. **Evelpidou, N.; Karkani, A.; Polidorou, M.; Saitis, G.; Zerefos, C.; Synolakis, C.; Repapis, C.; Tzouxanioti, M.; Gogou, M.** (2022). Palaeo-Tsunami Events on the Coasts of Cyprus. Geosciences, 12, 58. https://doi.org/10.3390/geosciences12020058
15. **Ferraioli, M.** (2019). Dynamic increase factor for nonlinear static analysis of RC frame buildings against progressive collapse. International Journal of Civil Engineering, 17(3), 281-303.
16. Geological Survey Department- Seismic Zoning Map of Cyprus. Retrieved from Event Map - GSD_Athena (gsd-seismology.org.cy)
17. **Hamed, M.** (2018). Comparative Study of Different Seismic Codes for Reinforced Concrete Buildings in Northern Cyprus, Near East University. International Building Code (2012).
18. **Işık, E.** (2021). A comparative study on the structural performance of an RC building based on updated seismic design codes: Case of Turkey. Challenge, 7, 123-134. https://doi.org/10.20528/cjsmec.2021.03.002
19. **Işık, E., Büyüksaraç, A., Ekinci, Y.L., Aydın, M.C., & Harirchian, E**. (2020). The effect of site-specific design spectrum on earthquake-building parameters: A case study from the Marmara region (NW Turkey). Applied Sciences, 10(20), 7247. https://doi.org/10.3390/app10207247
20. **Ismail, A.** (2014). Non linear static analysis of a retrofitted reinforced concrete building. HBRC Journal, 10(1), 100-107. https://doi.org/10.1016/j.hbrcj.2013.07.002
21. **Istiono, H., Susanti, E., Propika, J., & Ramadhan, A.Y.** (2022). Study comparison P-Delta Effect analysis depends on height variation of the building. Journal of Civil Engineering, Planning and Design, 1(1), 50-59.
22. KKTC Cumhurbaşkanlığı Toplantı (2022)
23. K.T.C. Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik 2015.
24. **Koçer, M.,Mehmet, U.Z. U.N., & Çöğürcü, M.T.** (2021). Comparison of TSC-2018 and TSC-2007 regulations for Konya in terms of equivalent earthquake load method. Konya Journal of Engineering Sciences, 9(3), 535-550. https://doi.org/10.36306/konjes.866044

25. **Lubkowski, Z.A., & Aluisi, B.** (2012, September). Deriving Ss and S1 parameters from PGA maps. In Proceedings of the 15th World Conference of Earthquake Engineering, Lisbon, Portugal (pp. 24-28).
26. **Moctar, H., Sadeghi, K.** (2023). Strong Column-Weak Beam Concept and Stiffness Factor Study for Moment Resisting Frames. International Journal of Innovative Science and Research Technology.
27. **Mule, N.R., Tupe, D.H., & Gandhe, G.R.** (2020). Analysis and Design of High Rise Building Subjected to Combined Effect of Earthquake and Strong Wind using E-Tab Software. International Research Journal of Engineering and Technology (IRJET), 07 (11), 1114-1119.
28. **Resatoglu, R., & Atiyah, R.S.** (2016). Evaluation of reinforced concrete buildings in Northern Cyprus using TEC2007 and EC8 in respect of cost estimation. Scientific Research and Essays, 11(19), 194-201.
29. **Resatoglu, R., & Hamed, M.** (2019). Comparative study of Different Seismic Codes for Reinforced Concrete Buildings in Northern Cyprus Using Static and Dynamic Methods. Journal of Engineering Science and Technology, 14(3), 1314-1329.
30. **Resatoglu, R., & Jkhsi, S.** (2022). Evaluation of Ductility of Reinforced Concrete Structures with Shear Walls having Different Thicknesses and Different Positions. IIUM Engineering Journal, 23(2), 32-44. https://doi.org/10.31436/iiumej.v23i2.2070
31. **Safkan, I.** (2012). Comparison of Eurocode 8 and Turkish Earthquake Code 2007 for Residential RC Buildings in Cyprus. In Proceedings of the 15th Conference on Earthquake Engineering, Lizbon, Portekiz.
32. SeismicPortal.eu, (2023) from www.seismicportal.eu
33. **Selcukhan, O., & Ekinci, A.** (2021). Liquefaction Potential Determination and Hazard Mapping Based on Standard Penetration Tests in Long Beach and Tuzla Regions of Cyprus. https://doi.org/10.21203/rs.3.rs-1077123/v1
34. **Selcukhan, O., & Ekinci, A.** (2023). Assessment of Liquefaction Hazard and Mapping Based on Standard Penetration Tests in the Long Beach and Tuzla Regions of Cyprus. Infrastructures, 8(6), 99. https://doi.org/10.3390/infrastructures8060099.
35. **Somwanshi, M.A., & Pantawane, R.N.** (2015). Seismic analysis of fixed based and base isolated building structures. International Journal of Multidisciplinary and Current Research, 3, 2321-3124. Türkiye Bina Deprem Yönetmeliği 2018 (TBDY-2018).
36. **Yadav, A., Hazari, D.** (2022). Static Pushover Analysis For Regular And Irregular Structures In All Zones. YMER Journal, 21(5).
37. **Yassin, A., & Sadeghi, K.** (2023). Structure Behaviour under Seismic loads using X-Bracing, Inverted V-Bracing Systems and without Bracing. International Journal of Innovative Science and Research Technology, Connections, 8(1).
38. **Zengin, B., & Aydin, F.** (2023). The Effect of Material Quality on Buildings Moderately and Heavily Damaged by the Kahramanmaraş Earthquakes. Applied Sciences, 13(19), 10668.

СПИСОК ЛИТЕРАТУРЫ

1. **Abd-Elhamed, A., Mahmoud, S.** (2016). Nonlinear static analysis of reinforced concrete framed buildings - A case study on Cairo earthquake. Journal of Engineering Research, Vol 4, No 4.
2. **Abraham, N.M., & SD, A.K.** (2019). Analysis of irregular structures under earthquake loads. Procedia Structural Integrity, 14, 806-819. https://doi.org/10.1016/j.prostr.2019.07.059
3. **Aksoylu, C., Mobark, A., Hakan Arslan, M., & Hakkı Erkan, İ.** (2020). A comparative study on ASCE 7-16, TBEC-2018 and TEC-2007 for reinforced concrete buildings. Revista de la Construcción, 19(2), 282-305.

4. ASCE 7: American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures from ASCE 7: Minimum Design Loads for Buildings and Other Structures (resource.org)
5. **Asim, K.M., Moustafa, S.S., Niaz, I.A., Elawadi, E.A., Iqbal, T., & Martínez-Álvarez, F.** (2020). Seismicity analysis and machine learning models for short-term low magnitude seismic activity predictions in Cyprus. Soil Dynamics and Earthquake Engineering, 130, 105932.
6. **Atmaca, N., Atmaca, A., & KILÇIK, S.** (2019). Comparison of 2018 and 2007 Turkish Earthquake Regulations. The International Journal of Energy and Engineering Sciences, 4(2), 19-25.
7. **Bhatt, C., & Bento, R.** (2014). A 3D pushover methodology for seismic assessment of plan asymmetric buildings. Earthq Spectra Earthq Eng Res Inst, 30(2), 683-703.
8. **Büyüksaraç, A., Işık, E., & Bektaş, Ö.** (2022). A comparative evaluation of earthquake code change on seismic parameter and structural analysis; a case of Turkey. Arabian Journal for Science and Engineering, 47(10), 12301-12321.
9. **Cagnan, Z., & Tanircan, G.B.** (2010). Seismic hazard assessment for Cyprus. Journal of Seismology, 14, 225-246. https://doi.org/10.1007/s10950-009-9163-1
10. Cyprus National Annex, Eurocode 8, Design of structures for earthquake resistance.
11. **Dindar, H., Akgün, M., Atalar, C., & Özdağ, Ö.C.** (2021). The assessment of local site effects and dynamic behaviour in Nicosia, Cyprus. G eofizika, 38(1), 61-80.
12. Earthquake.Zone, (2023), from https://earthquakes.zone/cyprus
13. **Elhadidy, M., Abdalzaher, M.S., & Gaber, H.** (2021). Up-to-date PSHA along the Gulf of Aqaba-Dead Sea transform fault. Soil Dynamics and Earthquake Engineering, 148, 106835. https://doi.org/10.1016/j.soildyn.2021.106835
14. **Evelpidou, N.; Karkani, A.; Polidorou, M.; Saitis, G.; Zerefos, C.; Synolakis, C.; Repapis, C.; Tzouxanioti, M.; Gogou, M.** (2022). Palaeo-Tsunami Events on the Coasts of Cyprus. Geosciences, 12, 58. https://doi.org/10.3390/geosciences12020058
15. **Ferraioli, M.** (2019). Dynamic increase factor for nonlinear static analysis of RC frame buildings against progressive collapse. International Journal of Civil Engineering, 17(3), 281-303.
16. Geological Survey Department- Seismic Zoning Map of Cyprus. Retrieved from Event Map - GSD_Athena (gsd-seismology.org.cy)
17. **Hamed, M.** (2018). Comparative Study of Different Seismic Codes for Reinforced Concrete Buildings in Northern Cyprus, Near East University. International Building Code (2012).
18. **Işık, E.** (2021). A comparative study on the structural performance of an RC building based on updated seismic design codes: Case of Turkey. Challenge, 7, 123-134. https://doi.org/10.20528/cjsmec.2021.03.002
19. **Işık, E., Büyüksaraç, A., Ekinci, Y.L., Aydın, M.C., & Harirchian, E**. (2020). The effect of site-specific design spectrum on earthquake-building parameters: A case study from the Marmara region (NW Turkey). Applied Sciences, 10(20), 7247. https://doi.org/10.3390/app10207247
20. **Ismail, A.** (2014). Non linear static analysis of a retrofitted reinforced concrete building. HBRC Journal, 10(1), 100-107. https://doi.org/10.1016/j.hbrcj.2013.07.002
21. **Istiono, H., Susanti, E., Propika, J., & Ramadhan, A.Y.** (2022). Study comparison P-Delta Effect analysis depends on height variation of the building. Journal of Civil Engineering, Planning and Design, 1(1), 50-59.
22. KKTC Cumhurbaşkanlığı Toplantı (2022)
23. K.T.C. Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik 2015.
24. **Koçer, M.,Mehmet, U.Z. U.N., & Çöğürcü, M.T.** (2021). Comparison of TSC-2018 and TSC-2007 regulations for Konya in terms of equivalent earthquake load method. Konya

Journal of Engineering Sciences, 9(3), 535-550. https://doi.org/10.36306/konjes.866044

25. **Lubkowski, Z.A., & Aluisi, B.** (2012, September). Deriving Ss and S1 parameters from PGA maps. In Proceedings of the 15th World Conference of Earthquake Engineering, Lisbon, Portugal (pp. 24-28).
26. **Moctar, H., Sadeghi, K.** (2023). Strong Column-Weak Beam Concept and Stiffness Factor Study for Moment Resisting Frames. International Journal of Innovative Science and Research Technology.
27. **Mule, N.R., Tupe, D.H., & Gandhe, G.R.** (2020). Analysis and Design of High Rise Building Subjected to Combined Effect of Earthquake and Strong Wind using E-Tab Software. International Research Journal of Engineering and Technology (IRJET), 07 (11), 1114-1119.
28. **Resatoglu, R., & Atiyah, R.S.** (2016). Evaluation of reinforced concrete buildings in Northern Cyprus using TEC2007 and EC8 in respect of cost estimation. Scientific Research and Essays, 11(19), 194-201.
29. **Resatoglu, R., & Hamed, M.** (2019). Comparative study of Different Seismic Codes for Reinforced Concrete Buildings in Northern Cyprus Using Static and Dynamic Methods. Journal of Engineering Science and Technology, 14(3), 1314-1329.
30. **Resatoglu, R., & Jkhsi, S.** (2022). Evaluation of Ductility of Reinforced Concrete Structures with Shear Walls having Different Thicknesses and Different Positions. IIUM Engineering Journal, 23(2), 32-44. https://doi.org/10.31436/iiumej.v23i2.2070
31. **Safkan, I.** (2012). Comparison of Eurocode 8 and Turkish Earthquake Code 2007 for Residential RC Buildings in Cyprus. In Proceedings of the 15th Conference on Earthquake Engineering, Lizbon, Portekiz.
32. SeismicPortal.eu, (2023) from www.seismicportal.eu
33. **Selcukhan, O., & Ekinci, A.** (2021). Liquefaction Potential Determination and Hazard Mapping Based on Standard Penetration Tests in Long Beach and Tuzla Regions of Cyprus. https://doi.org/10.21203/rs.3.rs-1077123/v1
34. **Selcukhan, O., & Ekinci, A.** (2023). Assessment of Liquefaction Hazard and Mapping Based on Standard Penetration Tests in the Long Beach and Tuzla Regions of Cyprus. Infrastructures, 8(6), 99. https://doi.org/10.3390/infrastructures8060099.
35. **Somwanshi, M.A., & Pantawane, R.N.** (2015). Seismic analysis of fixed based and base isolated building structures. International Journal of Multidisciplinary and Current Research, 3, 2321-3124. Türkiye Bina Deprem Yönetmeliği 2018 (TBDY-2018).
36. **Yadav, A., Hazari, D.** (2022). Static Pushover Analysis For Regular And Irregular Structures In All Zones. YMER Journal, 21(5).
37. **Yassin, A., & Sadeghi, K.** (2023). Structure Behaviour under Seismic loads using X-Bracing, Inverted V-Bracing Systems and without Bracing. International Journal of Innovative Science and Research Technology, Connections, 8(1).
38. **Zengin, B., & Aydin, F.** (2023). The Effect of Material Quality on Buildings Moderately and Heavily Damaged by the Kahramanmaraş Earthquakes. Applied Sciences, 13(19), 10668.

Amer Yassin - Master degree, M.Sc Student, Near East University, Faculty of Civil Engineering, Civil Engineering Department. E-mail: ameryaseen099@gmail.com

Rifat Resatoglu - PhD degree, Assoc. Prof. Dr, Near East University, Faculty of Civil Engineering, Civil Engineering Department. E-mail: rifat.resatoglu@neu.edu.tr

Амер Яссин - Студент магистратуры. Ближневосточный университет, факультет промышленного и гражданского строительства, кафедра промышленного и гражданского строительства. E-mail: ameryaseen099@gmail.com

Рифат Резатоглу - доцент, профессор, кандидат наук, Ближневосточный университет, факультет промышленного и гражданского строительства, кафедра промышленного и гражданского строительства. E-mail: rifat.resatoglu@neu.edu.tr