International Journal of Advanced Engineering and Technology
www.allengineeringjournal.com
ISSN: 2456-7655
Received: 13-07-2024, Accepted: 12-08-2024, Published: 27-08-2024
Volume 8, Issue 1, 2024, Page No. 29-35

Seismic analysis methods adopted for buildings design in Iraq: A review

Al-Naqdi Ibtehal Abdulmonem[1*], Mohammed Y Fattah[2]
[1] Ministry of Education, Directorate of School Buildings, Iraq
[2] Professor, Department of Civil Engineering, University of Technology, Iraq

Abstract
This study reviews the seismic analysis methods used for building design and analysis in Iraq's north, middle, and south provinces, citing seismic codes and standards from other authors' studies. Buildings studied by authors varied from reinforced concrete buildings to bearing walls buildings. From the review, it is obvious that the Pushover Method and Response Spectrum Model are more relevant and accurate and offer simplicity and save in cost when analyzing buildings considering seismic hazards. Both Time History Analysis and Equivalent Static Analysis have obvious disadvantages, as Time History Analysis is accurate but complex and requires significant expertise. On the other hand, Equivalent Static Analysis is simple and practical for design but it also has its disadvantages such as inaccuracy) Iraqi seismic code was taken by majority of authors in their researches for determining parameters used during assessing of seismic effect. From reviewed studies it is clear the need for Iraqi records of seismic activity in Iraq so that it can help authors in their researches.

Keywords: Seismic, Iraqi seismic code, RC building, Masonry building

Introduction

Iraq occurs in the northeastern portion of the Arabian Plate, which is now colliding with the Iranian (Eurasian) Plate. The active Zagros Seismic Belt is formed by the contact between the two continents, which exhibits seismic activity [1]. Iraq has recently encountered unprecedented seismic activity, particularly in the vicinity of the eastern boundary with Iran. This has underscored the necessity of reassessing the seismic hazard in this area [2]. The most crucial need is to develop a successful plan for at least a minimal decrease in damage caused by disasters [3, 4].

The code is essential for establishing the need for safe and healthy public buildings. Furthermore, rules target is to increase durability of existing constructions and promote a financial and high-quality approach, encompassing all necessary requirements for the design and implementation of constructions, bridges, and buildings. The code must ensure the geotechnical requirements are met, ensuring safe and suitable construction sites. Its purpose is to ensure the safety, durability, and affordability of buildings in various Iraqi regions, ensuring their durability and affordability [5].

The main purpose of civil engineering constructions is to resist static loads. In general, the effect of dynamic loads on the structure is overlooked. This characteristic of disregarding dynamic forces occasionally results in disaster, particularly due to an earthquake action. Ductility is required in the event of seismic forces. An important quality of a building that has to react to powerful ground movements is ductility [6].

Seismic analysis methods

Pushover Analysis (POA) is a nonlinear static approach that simulates relative inertia forces at high-mass regions by exposing a computer model to a preset lateral load pattern. The structure is "pushed" as the load intensity increases, leading to a series of fractures, yielding, and plastic hinge forms. The failure of various structural components is monitored based on the increasing lateral load, continuing until a set displacement limit is reached [7, 8].

A technique extensively used in building design is response spectrum analysis (RSA). This approach aims to provide rapid approximations of the peak response without involving a response history study. This is crucial due to the fact that response spectrum analysis needs rapid and simple computations, but time history analysis involves solving a differential equation of motion over time. In spite of its approximation, the approach permits a response spectrum, which helps portray earthquake seismic response [9].

Modal Analysis is used to simulate earthquake loads on a classically damped n-DOF structure. This construction might be a standard multistory frame, which is often utilized as a benchmark in comparable research [10].

The most advanced analytical technique is the Nonlinear Dynamic analytical (NDP) approach. It is often thought to provide "exact" answers to difficulties involving design or evaluation. As is the case with any analytical technique, the method's correctness is contingent upon the structure's modeling, the ground motion characteristics, and the nonlinear material models included in the calculations [8].

Simplified Methods is a hand static analysis that simplifies capacity concerns by ascertaining displacement capacity, lateral strength, and collapse process. Therefore, the capacity curve can be ascertained by comparing the displacement of the roof and the base shear of the structures [11]. Equivalent Static Analysis (ESA) is a method that uses empirical formulae to calculate the inertia forces as static forces. The approach may be used for irregular structures with some restrictions, but it is highly advised for regular ones with uniform mass and stiffness distribution, uniform shape, and uniform statical system. [12]. Time History Analysis (THA) is a step-by-step process that evaluates loading and response history at consecutive time increments (Δt). During each step, the response is assessed based on the starting circumstances (displacements and velocities) and the loading history in the interval. This approach allows one to readily examine the non-linear behavior by varying the structural parameters (e.g., stiffness, k) from one step to the next [13].

Seismic analysis for buildings in Iraqi provinces

1. Middle proveniences

Hasan *et al*. [14] investigated four-story reinforced concrete residential buildings in Baghdad, the capital of Iraq, to assess the response spectrum model's and equivalent lateral force method's dependability. The analysis for irregular structures was conducted using the Iraqi Seismic Code (ISC 2016). In accordance with ASCE 7-16, the American Society of Civil Engineers, the irregularity categorization was selected. ASCE 7-16 set the risk category II building story drift limit at 2%. According to the research, the NDP (nonlinear dynamic process) results best depict the building's nonlinear behavior.

Mustafa and AbdulMuttalib [2] used probabilistic and deterministic methodologies to analyze seismic hazards at Baghdad's Al-Tajiat and Al-Zawraa stadiums. The authors used temporal histories of several occurrences from Iran, Turkey, and Armenia for spectral analysis since Iraq had no data. Authors stated that the design model developed from data meeting the ISIRI 2800 and UBC 1997 process requirements is more conservative and provides more realistic safety margins [15].

Majdi and Vacareanu [16] utilized FEMA P-58 methodology to assess seismic damage on a multi-story reinforced concrete building at Al-Mustaqbal University College in central Iraq. The authors conducted pushover analysis and 3D mathematical modeling using the SeismoStruct program. To assess the limits of the risk condition of damage in relation to the case study building's performance levels, an incremental dynamic analysis (IDA) and a fragility curve were developed in compliance with FEMA P-58. The authors followed the recommendations of the new Iraqi seismic code and ASCE/SEI 7-10.

In 2012, the Ali Al-Gharbee earthquake damaged Maysan Province in southern Iraq. In response, Salman *et al.* [17] used SAP2000 to construct a three-dimensional finite element model of a reinforced concrete structure in Baghdad's Alkarada district. The study utilized three methods to determine the building's response to an earthquake: time history analysis, Response spectrum analysis, and the equivalent static method. The time history analysis focused on mode superposition analysis; the response spectrum analysis assessed the dynamic effects of ground motions; and the equivalent static method assessed force. Response spectrum analysis was clearly more accurate for building analysis, even under earthquake influence, and the Iraqi Seismic Code aligns with other seismic codes, demonstrating its effectiveness in assessing buildings. [17, 18].

Al-Nuaimi *et al*. [19, 20] used two variations of the capacity spectrum method suggested in ATC 40 and ATC 55 to assess the seismicity demands derived from nonlinear static analysis procedures, as well as the performance objectives included in the Iraqi Seismic Code (ISC) for Performance-Based Seismic Design of two groups of multi-story RC buildings. The authors conducted pushover studies in Baghdad and Duhok provinces to investigate the nonlinear behavior of structures under three seismic danger categories, evaluating performance targets in the Iraqi Seismic Code.

The ARIF W [14] research investigated the seismic activity of multi-story reinforced concrete frames in Baghdad province, Iraq, using three analytical methods: equivalent lateral force technique, nonlinear static procedure, and nonlinear dynamic procedure [21].

From the results, it was concluded that the equivalent lateral force analysis, which is considered in the Iraqi code ISC 2016 to analyze and design the buildings in Iraq, is not appropriate for the analysis of setback structures. As a result, it was imperative to implement more effective and suitable methodologies for the analysis of performance and design of reinforced concrete buildings.

2. South proveniences

Al-Jassim and Raheem [22] examined the performance of two six-story reinforced concrete buildings with and without shear walls due to seismic action. This investigation uses focused plasticity with a nonlinear time history to forecast seismic intensity in a region using the spectrum matching method to scale three time-acceleration recordings from the Iraqi seismic code-2017, Uniform Building Code-1997, and International Building Code-2012. The IBC2012 code concerned with the area studied gave the greatest values for seismicity, while the Iraqi seismic code ISC2017 gave the smallest values.

Al-Jassim and Abdul Hussain [23] conducted a nonlinear static analysis (pushover analysis) of an extant G+5-story reinforced concrete building in Basrah city, utilizing the ATC40 capacity spectrum method. The authors examined three types of cases: regular, irregular in plan, and irregular in height. For seismic analysis, the authors used seismic coefficients from the UBC97 code. This showed that nonlinear static analysis (pushover analysis) is easier for low to moderately-high buildings than nonlinear time history analysis. Nonlinear static analysis can analyze the building's reaction to seismic events, forecast the degradation of a structure's stiffness the development and position of plastic hinges, and identify important elements during an earthquake. ATC40 employs a response spectrum approach for concrete structures, starting with the 5% damped elastic spectrum and progressing to the final reduced spectrum.

Alshaheen and Al-Jassim [24] performed nonlinear time history analysis for asymmetrical reinforced concrete buildings to assess seismic response. The building was located in Basra province in the south of Iraq. The authors updated ISC2017 to include seismic requirements for new buildings, not existing ones. They studied 11 ground motion real records using the PEER online tool and scaled them to the Basrah level of earthquakes using the spectrum matchings method. Each of the 11 ground motions was scaled by the software SeismoMatch 2021. The P-delta effect is a feature of the SAP2000 program that was used to analyze geometric nonlinearity.

Al-Mamoori *et al*. [25] clarified the background of seismic activity in Iraq using seismology data from the United States Geological Survey Agency (USGA) over the previous 60 years. The seismic magnitude data (as determined by the Richter scale) that the USGS collected from 1950 to 2019 was illustrated in Figure 1. In order to ascertain the site class, SPT was conducted according to ASTM (D-1586). In order to simulate interpolation maps, Arc-Map 10.5 was used. For representing SPT-N data, authors used IDW method due to its reliability and suitability. Parameters were determined according to the American standards ASCE 7–16 and the Iraqi Seismic Code.

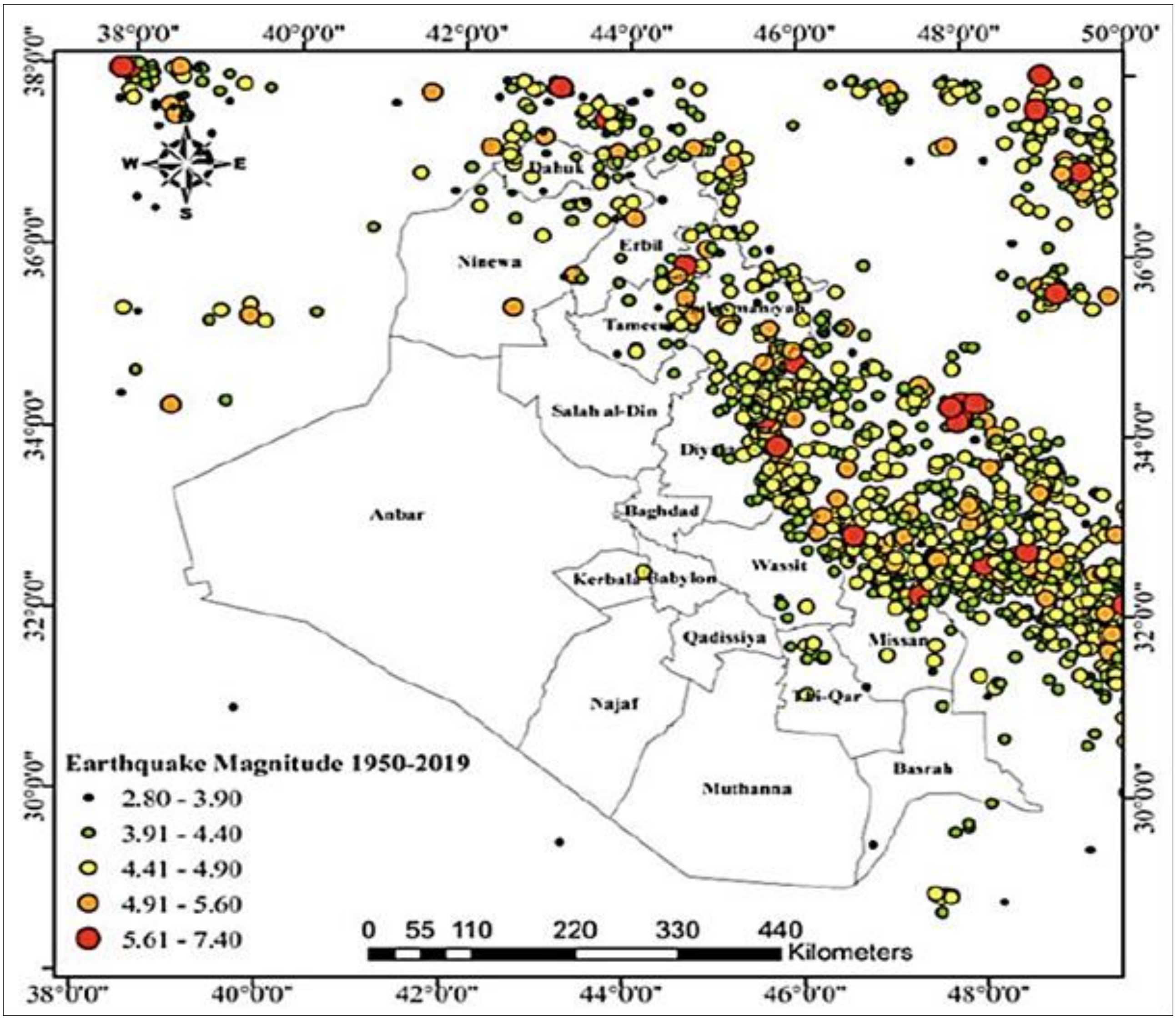


Fig 1: Data of Iraq Seismic magnitude during the period 1950–2019 [25]

3. North proveniences

Abdi and Yaseen [26] examined six existing RC buildings. The buildings were modeled and analyzed using the ETABS V.18 program. Nonlinear static (pushover) analysis was used in the study. Furthermore, the status of seismic behavior of the structures under the seismic impact for the city was evaluated using the modified capacity spectrum approach of FEMA 440. The structures' overall structural damage is minimal, yet the lower story columns show some cracking. The authors advised reinforcing columns at ground level. Authors concluded that low-intensity performance assessment using Iraqi seismic code for highest seismic danger level produces satisfactory findings.

Ahmed, Y. [27] conducted a pushover analysis on a reinforced concrete frame in Mosul city, assessing seismic hazard using SAP2000 software (V.14). The seismic performance of a building was evaluated using the principles of Performance Based Seismic Engineering, which integrate seismic hazard assessment with inelastic structural analysis. The building's ability to withstand a specific level of seismic load was demonstrated by lateral deformations at the performance point. Undoubtedly, the structure conforms to the strong column-weak beam mechanism; however, the Applied Technology Council (ATC-40) structural performance categories consider the established hinges hazardous and require enhancement. The authors' analysis was based on the 1997 UBC unified building code.

Mohammed *et al*.[28] conducted research where they compared the results obtained from Iraqi seismic codes with those obtained from time history analysis using Halabja earthquake loads (2017). The purpose of the study was to evaluate and improve the ISC 2017 parameters. Five models of the multi-story concrete structure were analyzed using ETABS structural software using time history and analogous static approaches. The most recent Iraqi Standard (ISC 2017) seems to be more conservative than the previous one (ISC 1997).

Abdulhameed and Taha [29] study calculates the unified hazard spectrum (UHS) using Sayhan's spreadsheet from the PEER research center (PEER, 2018), and extracts the necessary parameters from a review of seismology and geology. Figure 2 presents the design response spectrum graph for Erbil city. According to the ASCE code (ASCE07-10), Various codes, including the Iraqi code, determine the site class.

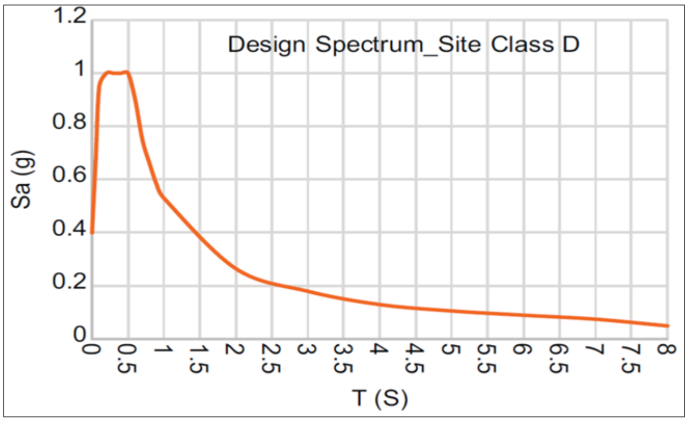


Fig 2: Response spectrum of Erbil city (site Class D) [29]

In the research of Mohammed *et al.* [30] there were three methods adopted by authors for analysis of the steel multistory building. Time history analysis depends on the real earthquake data of Halalabja earthquake (acceleration-time) history, and two other methods depend on the principle of equivalent static method proposed by Iraqi Seismic Codes presented in 1997 and 2017.

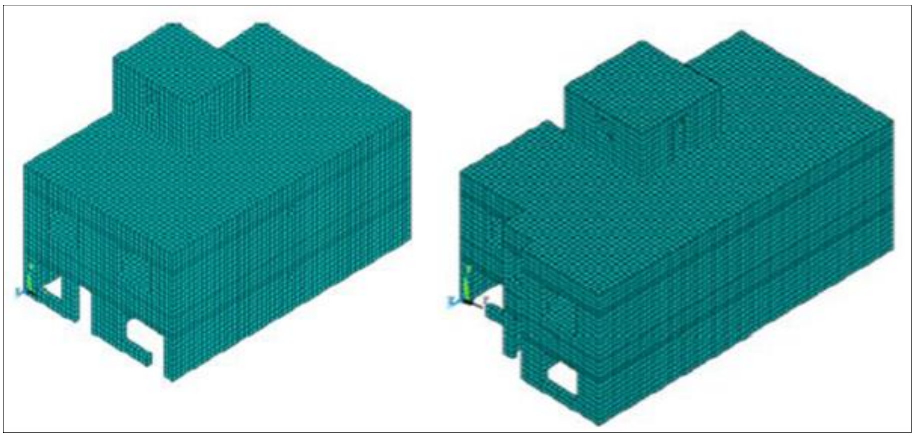
MATLAB was used to calculate the dynamic response of a four-story shear structure in the Hussein [31] research. The proposed structure was believed to be located inside the seismic zone of Erbil City. To conduct reaction spectrum analysis of a multi-degree-of-freedom shear frame under ground motion stimulation in the Erbil seismic zone (site class B), the standard technique outlined in the International Building Code was used. The IBC regulation mandates that the seismic maps provided by the United States be used to determine the spectral response acceleration factors [31].

Haido [32] utilized the static analysis approach for UBC 97 code, which was accessible in ETABS. A new design spectrum has been proposed for seismic dynamic analysis based on spectra values from various design codes, including UBC 97, IBC 2003, IBC 2006, Euro code 1998, Euro code 2004, New Zealand code NZS 1992, Chinese standards 2010, Canada standards NBCC 1995, NBCC 2005, Australian standards 2007, Italian standards 3274. For the aforementioned codes, the usual design response spectrum data was developed based on the Duhok city seismic coefficients. For this area and all of Iraq, there was no set code. To confirm the validity of the analytical technique, it was crucial to examine the impact of new inertia reduction variables on the existing spectrum.

Abbas and Jarallah [33] employed ISC-2017 to calculate the MCE and DBE elastic response spectra. The acceleration data for the Halabjah earthquake were gathered from the Iraqi seismic network operated by the Iraqi Meteorological Organization and Seismology. The two components were investigated, and the response spectrum was generated using the PRISM program. The pushover research ascertains the building levels.

4. Masonry buildings

Alkenanee and Alrudaini [34] conducted 3D FE modeling for two houses with regular and semi- regular plan applying nonlinear static pushover analyses to represent the capacity curves of models. The results of the research were verified with experimental results in the literature. Masonry walls were modeled using equivalent homogeneous isotropic macro model that has properties accounting for the interaction effect of both bricks and mortar. Modeling was performed with the help of ANSYS 11.0 software, where three-dimensional solid elements (SOILD 65) werw used to model the wall (Figure 3). Nonlinear stress strain curve was presented to model, the nonlinear performance of masonry walls that simulates the combined effect of bricks and mortar. The seismic demands were obtained based on the spectrum accelerations recommended by the Iraqi seismic code.



House 1 **House 2**

Fig 3: Finite element modeling of the houses [34]

Abbas and Hameed [35] utilized ABAQUS 6.13 software to create a single-story home. Masonry walls reinforced concrete slabs, and lintels were simulated using the brick element (C3D8R) to simulate the rebar characteristics used in the slab and lintel truss elements (T3D2). Concrete Damage Plasticity model CDP was chosen because of the brittleness and low tensile strength of concrete and masonry. To simulate the inelastic behavior of concrete, the CDP in ABAQUS combined the idea of isotropic damage with isotropic tensile and compression plasticity. The drift and maximum displacement of masonry buildings were calculated, as well as the seismic performance was assessed, using the modal analysis. In this research, the time history analysis approach was used.

Target drift was determined with the help of minimum design loads for buildings and other structures, "ASCE Standard ASCE/SEI 7-10".

Kadhim and Dawood [36], in their research, used the transient analysis (also called time-history) allowed in ANSYS mechanical APDL software for a one-story, single room. In this sort of analysis, ANSYS solves the equilibrium equations in their entirety. During numerical analysis of structure, severe cracks had been formed in both Unreinforced Masonry and Confined Masonry structures, this was related to their unsafety under seismic effect. The minor cracks in concrete in the confined masonry building compared to the severe ones in the masonry walls of the same structure proved the capability of the confinement to prevent the disintegration of collapsed masonry walls, at least in damaging cases like the building state at the solution termination.

Professional software like Seismosignal uses the double integration technique to convert acceleration time histories to displacement time histories. The research comprised displacement time records from the November 12, 2017, 7.3 Mw earthquake that hit the border between Iraq and Iran, together with an analysis of seismic data from the PEER Berkeley ground motion database. The Iranian Strong Motion Database website provided the ground acceleration files for the earthquake in question. Compared to the nonlinear, static analysis (pushover analysis), the nonlinear, dynamic analysis seems more conservative [37]. Sets of records were chosen for each seismic danger zone (A and B) in Yaseen *et al.* [38] research based on general record characteristics. Every document was taken out of the PEER NGA flat file database. Comparing records utilizing other ground motion selection techniques (EC8, CMS, and Jayaram *et al*. algorithm) with the set of records matching KR's suggested response spectrum, the nonlinear time history analysis revealed that the former may properly forecast the mean response of unreinforced masonry structures. Additionally, the greater drift value of the examined buildings showed that these kinds of structures need to be reinforced in order to avoid collapse since they are very sensitive to seismic stresses [37].

Yaseen and Ahmed [38] proved that incremental Dynamic Analysis (IDA) is one of the accurate methods that can be used for that purpose. The IDA process is sometimes referred to as a "dynamic" pushover procedure since it generates dynamic capacity curves for various ground motion levels. By scaling the ground motion time history to different intensities, IDA performs several nonlinear dynamic evaluations of a structural model until the full capacity curve was created.

5. Results and discussion

According to the analyzed research, the greatest percentage of pushover analysis methodologies employed in seismic analysis for RC and masonry structures across Iraqi provinces was 43.75%. The response spectrum model (RSA), which has a 37.5% approval rate, is very desirable to practicing engineers since it uses a response spectrum to characterize seismic loading. Using a code-compliant, generally smooth response spectrum that may be readily changed depending on the site seismic hazard, all design codes globally describe seismic input or hazard [7]. The minimum percentage was 6.25% for time history in addition to the equivalent method. The dynamic RS analysis approach is recommended for seismic design due to its computational benefits in forecasting structural system response. However, before distributing lateral seismic pressures throughout the structure, the design base shear is scaled using The ESF analysis approach, ensuring accurate and efficient seismic design [10]. A comparison of percentages for using different methods by authors to assess seismic hazard during analysis and design of buildings is shown in Figure 4.

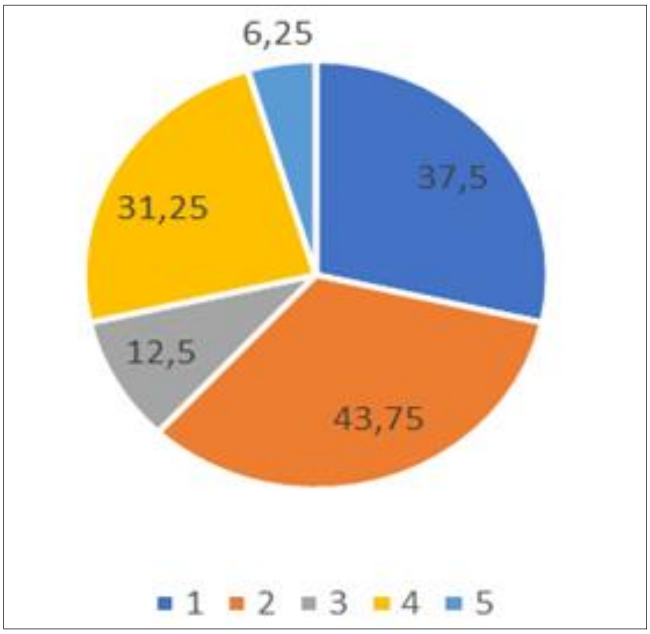
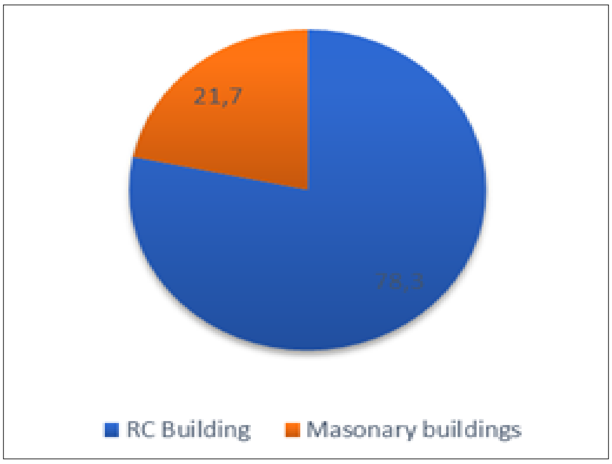
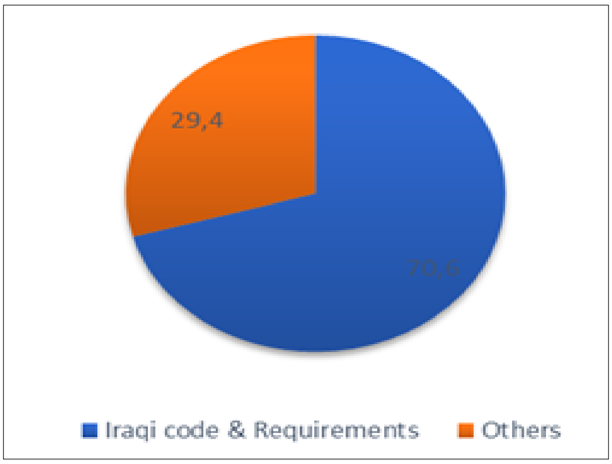


Fig 4: Percentage (%) for the use of seismic analysis methods by authors:1. Response spectrum model; 2. Nonlinear static analysis (pushover analysis); 3. Time history analysis + Response Spectrum Analysis; 4. Nonlinear time history analysis; 5. Time history + equivalent

About 78.3% of building models taken by authors were reinforced concrete buildings as 21.7% were masonry buildings, as shown in (Figure 5, a). It was noted that most of the buildings built in Iraq lacked taking seismic effect into consideration. About 70.6% of authors' studie depended on the Iraqi seismic code and requirements in assessing seismic hazard effect in order to define parameters used in seismic analysis. While 29.4% of studies excluded this code and requirements in their studies (Figure 5, b).



a



b

Fig 5: Percentage (%) for a)- Building style for studied buildings taken by authors, b)- For codes and requirements taken by authors for seismic assessment for reinforced concrete buildings.

For small values of the base shear force (few plastic hinges), the results of the time history analysis may differ from the pushover curves, but as the importance of the base shear force increases (more plastic hinges), these tend to become closer to the pushover curve. Starting from the time history, the response spectrum itself can be obtained by analyzing the response of simple system oscillators with natural time differences and effects from the ground motion history.

Spectra obtained from ground data are quite rough. In practice, smoothed generation spectra are often used, which allow for the uncertainties associated with future ground motions to be considered. When historical analysis is used to generate response spectra, appropriate ground motions representative of the target's seismic hazard is needed. A set of amplitude-scaled ground motions can be used whose average response spectrum matches the standard response spectrum (DRS) of the target. But this takes a lot of work and requires a lot of calculations.

Conclusions

1. Using Pushover model and response spectrum analysis gives more accurate results after analyzing buildings, even under the influence of earthquakes.
2. The Iraqi Seismic Code (ISC) has successfully achieved its goals. If the building is correctly built and constructed, and the goals of the Iraqi Seismic Code (ISC) are satisfied, safety and integrity will be ensured.
3. There is a serious and tremendous need for records of seismic activities in Iraq, as this will be helpful to a great degree to a wide spectrum of researchers to assess seismic hazards in Iraq.
4. The minimum percentage of methods used by authors to assess seismic hazard was for time history in addition to the equivalent method.
5. The studies performed to estimate seismic effect were mainly for reinforced concrete buildings, although there is a high percentage for buildings of masonry bearing walls in Iraq. Programs ANSYS APDL and ABAQUS were used to design masonry buildings during earthquakes.

Recommendations

1. More future researches are recommended considering public buildings such as one and two-story masonry schools, health centers and two-story office buildings that are common practice masonry buildings in Iraq.
2. The need to enhance and update ISC2017 code to include assessment of existing buildings not only for new buildings to be built.
3. Requirements for more studies to qualify for the Iraqi seismic code.
4. Soil investigation must be performed instead of considering the site class as D. For this reason, it is important to create a seismic database for all cities of Iraq.

Acknowledgments

Acknowledgments goes to the Ministry of Education and the Directorate of School Buildings in Iraq for their support.

References

1. Mohammed JGh, Abdul Ahad AD, Jabbo BR. The 11th March 2013 earthquake in the north of Mosul vicinity, north Iraq. Iraqi Bull Geol Mining,2014:10(1):59-72.
2. Farman MS, Said AI. Updated probabilistic seismic hazard assessment for Iraq/2018. Civ Eng J,2018:4(7):1610-28. Available from: http://dx.doi.org/10.28991/cej-0309199
3. Yaseen AA, Ahmed MS. Seismic vulnerability assessment of single-story masonry buildings in Kurdistan Region-Iraq. Acad J Nawroz Univ,2018:7(4):18-26.
4. Fattah MY, Al-Tae'e AY. Seismic conditions in Baghdad region and evaluation of seismic design forces. J Eng Coll Eng Baghdad,2004:10(2):399-412.
5. Al-Taie E, Al-Ansari N, Knutsson S. The need to develop a building code for Iraq. Eng,2014:6(10):610-632. Available from: http://creativecommons.org/licenses/by/4.0/
6. Gottala A, Kishore KS N, Yajdhani S. Comparative study of static and dynamic seismic analysis of a multistoried building. Int J Sci Technol Eng,2015:2(01):173-83.
7. Themelis S. Pushover analysis for seismic assessment and design of structures. [dissertation]. Heriot-Watt University, 2008.
8. Fattah MY, Hamood MJ. Comparison between different codes for evaluation of seismic forces on a multi-storey building in Baghdad City. Eng Technol J,2003:22(6):313-25.

9. Fragiadakis M. Response spectrum analysis of structures subjected to seismic actions. In: Encyclopedia of Earthquake Engineering, 2013 ,3-18.
10. Fu ZF, He J. Modal analysis. 1st ed. Amsterdam: Elsevier: 2001. Available from: https://doi.org/10.1016/B978-0-7506-5079-3.X5000-1
11. Tehranizadeh M, Amirmojahedi M, Moshref M. Simplified methods for seismic assessment of existing buildings. Earthq Struct,2016:10(6):1405-28. Available from: http://dx.doi.org/10.12989/eas.2016.10.6.1405
12. Mahmoud S, Abdallah W. Response analysis of multi-storey RC buildings under equivalent static and dynamic loads according to Egyptian code. Int J Civil Struct Eng Res,2014:2(1):79-88.
13. Domingues CJ. Standard methods for seismic analyses. Byg Rapport, 2003, r-064:. Available from: http://www.byg.dtu.dk/publications/rapporter/r-064.pdf
14. Hasan HH, Arif WM, Sulaiman EA. Seismic analysis of RC building with plan irregularity in Baghdad/Iraq to obtain the optimal behavior. Open Eng,2024:14(1):20240003. Available from: https://doi.org/10.1515/eng-2024-0003
15. Norouzi N, Mojarab M, Asadi Z, Zare M. A case study of seismic hazard analysis at Al-Tajiat and Al-Zawraa stadiums in Baghdad/Iraq region. Arab J Sci Eng,2015:40(7):1987-2002. Available from: https://doi.org/10.1007/s13369-014-1559-8
16. Majdi A, Vacareanu R. Evaluation of seismic damage to Iraqi educational reinforced concrete buildings using FEMA P-58 methodology. In: IOP Conf Ser: Earth Environ Sci,2021:664(1):012-110. IOP Publishing. Available from: https://doi.org/10.1088/1755-1315/664/1/012110
17. Salman MR, Abbas HA, Ghaltan HM. Modelling analysis of earthquake impact on RC buildings in Baghdad using SAP200. J Appl Eng Des Simul,2023:3(2):49-56. Available from: https://doi.org/10.24191/jaeds.v3i2.69
18. Abdulaziz MA, Hamood MJ, Fattah MY. A review study on seismic behavior of individual and adjacent structures considering the soil–structure interaction. Struct,2023:52:348-69. Available from: https://doi.org/10.1016/j.istruc.2023.03.186
19. Al-Nuaimi A, Sobaih M, Adel A. Investigation of effects of capacity spectrum method on performance evaluation of multi-story buildings according to the Iraqi seismic code requirements. Open J Civil Eng,2016:6(3):420-41. Available from: http://dx.doi.org/10.4236/ojce.2016.63036
20. Alnuaimi Bayasi AMZ, Mohammad FA. Investigation of effects of displacement coefficient method on performance evaluation of multi-story buildings according to the Iraqi seismic code requirements.
21. Arif W. Seismic behavior and analysis of irregular RC structures. [thesis]. Technical University of Civil Engineering Bucharest, 2021.
22. Al-Jassim SAB, Raheem HA. Seismic analysis of reinforced concrete buildings in south of Iraq based on different codes. Int J Eng Technol,2018:7(4.20):51. Available from: https://doi.org/10.14419/ijet.v7i4.20.25849
23. Al-Jassim SAB, Abdul Hussain M. Pushover analysis of G+5 reinforced concrete building in Basrah. Int J Innov Eng Technol,2018:8(1):36-45. Available from: http://dx.doi.org/10.21172/ijiet.111.10
24. Alshaheen AS, AlJassim SAJ. Seismic assessment of asymmetrical existing RC building in south of Iraq by nonlinear time history analysis. Univ Thi-Qar J Eng Sci,2022:12(1):26-31. Available from: http://www.doi.org/10.31663/tqujes.12.1.417
25. Al-Mamoori SK, Attiyah AN, Al-Maliki LA, Al-Sulttani AH, El-Tawil K, Hussain HM. Seismic risk assessment of reinforced concrete frames at Al-Najaf City-Iraq using geotechnical parameters. In: Modern Applications of Geotechnical Engineering and Construction: Geotechnical Engineering and Construction. Singapore: Springer Singapore, 2020, 329-348. Available from: https://doi.org/10.1007/978-981-15-9399-4_28
26. Abdi IA, Yaseen AA. Seismic vulnerability assessment of existing RC multi-story buildings in Duhok City, Kurdistan region of Iraq. J Duhok Univ,2021:24(1):60-78. Available from: https://doi.org/10.26682/sjuod.2021.24.1.9
27. Ahmed Y. Seismic evaluation of reinforced concrete frames using pushover analysis. Al-Rafidain Eng J,2013:21(3):28-45.
28. Mohammed AR, Abdulwahed LR, Rashid B. Seismic structural analysis of multi-story concrete building based on Halabja 2017 earthquake. J Eng Sci Technol,2022:17(6):4092-106.
29. Abduljaleel ZA, Taha BO. Review of seismic characteristics in Erbil city, the capital of the Kurdistan Region of Iraq. Polytech J,2019:9(2):27.
30. Mohammed AR, Al-Qaisee GS, Rashid B. Analysis of steel multi-storey building subjected to Halabja earthquake loading. In: IOP Conf Ser: Mater Sci Eng,2020:881(1):012039. IOP Publishing. Available from: https://doi.org/10.1088/1757-899X/881/1/012039
31. Hussein A. Dynamic response spectrum of multi-story shear frame subjected to moderate ground motion. Diyala J Eng Sci,2021:14(1):71-9. Available from: https://doi.org/10.24237/djes.2021.14207
32. Haido JH. Prediction of RC multi-story construction performance with a new proposed design spectrum approach. Tikrit J Eng Sci,2015:22(1):52-68. Available from: https://doi.org/10.25130/tjes.v22i1.524
33. Abass HA, Jarallah HK. Plastic hinge zone effect on seismic evaluation of RC frame under Iraqi seismic code loading. In: 2021 Int Conf Adv Sustain Eng Appl (ICASEA). IEEE, 2021, 159-64.
34. Alkenanee FS, Alrudaini TMS. Seismic performance of masonry buildings in Iraq. Res Eng Struct Mater. 2023. Available from: http://dx.doi.org/10.17515/resm2022.489ie0801
35. Abbas AL, Hameed MI. Evaluate the seismic performance of a masonry bearing wall structure in Iraq. In: 2018 1st International Scientific Conference of Engineering Sciences-3rd Scientific Conference of Engineering Science (ISCES): 2018: [place of publication unknown]: IEEE,2018,243-8.
36. Kadhim JA, Dawood AO. Seismic performance of clay bricks construction. Civ Eng J,2020:6(4):785-805.
37. Yaseen AA, Begg D, Nanos N. Time history analysis of existing buildings in the Kurdistan region of Iraq. IEC2014, 2014, 1.
38. Yaseen AA, Ahmed MS. Seismic vulnerability assessment of single-story masonry buildings in Kurdistan region-Iraq. Acad J Nawroz Univ,2018:7(4):18-26.