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Dynamic Analysis of a Multistory Building Using Response Spectrum Method

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Abstract

Designing and analyzing structures to mitigate the effects of earthquakes is considered important, especially in recent times when earthquakes have increased in many places. This research includes analyzing a structure consisting of a basement and (G+14) stories, which encompasses a plan area measuring 32.20 m * 30.70 m. The building comprises a basement level serving as a car garage and 15 residential stories within coordinates (34.19205N) (45.12537E). The response spectrum analysis method, a linear dynamic method, was used, and the ETABS 21 program was adopted to perform this task. The conditions for the analysis in this way were done according to the ASCE/SEI7-16 code. This method includes several steps, where, in the beginning, the response spectrum function is defined, the earthquake is defined in the direction of both X and Y, and the source of the mass is determined. The effect of the geometric nonlinearity is also considered, in addition to 30 mode shapes, to reach the mass participation ratio equal to 100%. In order to perform the mentioned steps, several important variables must be entered, which are the reduction factor (R=4), spectral acceleration in the short and long direction (Ss=0.8, sl=0.2), and the damping value (5%). The analysis results included calculating the period, the center of mass and rigidity, but the main objective of this research was to calculate the base shear, which amounted to 2077 tons, and the story drift of the structure, which amounted to 0.0479. This value is considered high, as it exceeded the permissible value specified by the ASCE/SEI7-16 code, and therefore, the structure is considered unsafe in the event of an earthquake.

Keywords— Response spectrum analysis, Base shear, Story drift, ETABS 21, GIS10.8

1 Introduction

One of the most devastating natural disasters is an earthquake. This cataclysmic event arises from the abrupt and momentary movement of the Earth's surface, which releases stored elastic energy within a matter of seconds. Additionally, earthquakes manifest as violent tremors caused by sudden shifts in the rock beneath the Earth's crust (Shearer, 2009). The event's impact is incredibly distressing due to its wide-reaching effects, sudden occurrence, and unpredictability. Earthquakes have the potential to result in significant loss of life and property, as well as the disruption of crucial services like water supply, sewerage systems, communication, power, and transportation. Not only do earthquakes devastate villages, towns, and cities, but their aftermath also destabilizes the economic and social fabric of the entire nation (Soni et al., 2012).

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Since 1980, earthquakes have accounted for 12.2% of all devastating natural occurrences, resulting in over 50% of total fatalities and 25.2% of economic losses. China, Indonesia, Iran, Turkey, and Japan have been the countries most impacted by destructive earthquakes. According to the earthquake damage index, these five nations have contributed (16%, 10%, 8%, 4.5%, and 4%) respectively to the overall devastation caused by earthquakes (Kamranzad et al., 2020). The seismicity of Iraq has been studied by many researchers, such as (S. Alsinawi & Ghalib, 1975), (Issa, 1983), and (Al-Dabbagh, 1999). All the studies of the seismicity and seismotectonic of Iraq indicated that seismic activity is moderate to high at northern and northeastern boundaries, which border Turkey and Iran (It is worth noting that both Turkey and Iran have endured destructive earthquakes and are among the top five countries severely impacted by such natural disasters) and decrease in the south and southeastern direction (S. A. Alsinawi, 2002)

Data from probabilistic seismic hazard assessment as well as several other seismicity studies conducted by (S. A. Alsinawi & Al-Qasrani, 2003) and (Ameer et al., 2005) show that Iraq is dominated by moderate to heavily damaging earthquakes. (Wang et al., 2016) and (Said & Farman, 2018) present studies for Iraq at different time intervals, showing medium-to-high earthquakes occur in the region at shallow depths, but the magnitude (Mw) rarely exceeds 7.0. (Mw is the moment magnitude scale). Therefore, when designing or analyzing buildings, it is necessary to consider the effect of earthquakes.

Many seismic studies have been carried out in Iraq to determine the performance of structures and identify seismically hazardous areas. The researchers (Y. Ahmed, 2013) (Abdi & Yaseen, 2021) (Al-jassim & Husssain, 2018) (Yaseen, 2020) (Amer et al., 2016) adopted the Pushover method for analyzing structures in their study. At the same time, researchers (Abdulnaby et al., 2014)(Ameer et al., 2005) (Said & Farman, 2018) continued in the Probabilistic seismic hazard analysis field. One of the well-known analysis methods is the response spectrum method (RSA). The use of RSA is essential in the design and evaluation of structures in regions prone to earthquakes. Analyzing the response spectrum makes it possible to enhance the seismic performance of buildings by optimizing structural parameters and carefully selecting appropriate materials during the design phase.

(Chandak, 2012) Investigated the seismic response of concrete buildings. The research depends on the design spectra recommended by the Indian Standard (IS) Code. Sample buildings were considered. SAP2000 software was used to perform elastic analysis and evaluate the buildings' seismic response. The comparative analysis revealed that the base shear was high. (Hassaballa et al., 2013) researched 'Evaluation of Seismic Analysis of Multistory Reinforced Concrete Buildings in Khartoum Region- Sudan' using the response spectrum technique. This study sought to evaluate the performance of the building during a moderate-intensity earthquake under the Sudan seismic code. The experimental data showed that nodal displacements caused drifts beyond permissible levels. (Sharma & Maru, 2014) Conducted a study to understand the dynamic analysis of multistory regular buildings in India. To assess the behavioral characteristics of the normal building with G+30, the researchers followed the parameters as per I S 1893 for Zones 2 and 3, which are low and medium, respectively, using STAAD-Pro software. The study also contrasts the findings obtained from dynamic and static analysis. (Choudhary & Bokare, 2018) employed two methods: the Response Spectrum Method (RSM) and the Seismic Coefficient Method (SCM). The investigation was carried out in the G+10 floor building in zone IV (moderate earthquake) of India. The researchers employed the sophisticated STAAD-PRO-V8i software. The research aimed to determine which of the two methods was accurate in its calculations. From the results obtained, it was established that RSM proved to be more comprehensive than SCM.

A study was (S. R. Kangle, 2020) conducted focused on RSA for Multistory Structures. The research examined a commercial building (G+15) in Seismic Zone III, classified as a moderate seismic zone. The authors utilized STAADPRO software to analyze the dynamic behavior of the building in accordance with IS: 1893 for seismic design. It was discovered that multistory structures exhibit significant stiffness when subjected to earthquake forces, primarily due to a modal participation factor exceeding 75 percent. In a study conducted by (Anirudh Raajan et al., 2021) a G+4 RC building was analyzed using the Response spectrum method. The building was designed to be located on a sloped surface and had mass irregularities. Specifically, the building was intended for disaster use, with one story dedicated to storing food and water and another for sleeping during emergencies. The structure was modeled using ETABS software in different seismic zones (III, IV, V). The findings revealed that the building experienced the least maximum story drift in all zones and directions. Therefore, utilizing the fifth story for food and water storage in all three seismic zones is recommended, ensuring safety during disasters. A recent study by (Hussein, 2021) focused on examining the Dynamic Response Spectrum of a Multistory Shear Frame during a Moderate earthquake. A simplified model of a four-story building was utilized to analyze the response spectrum based on the International Building Code. Through the use of MATLAB® code, various parameters such as mode shapes, response spectrum acceleration, maximum displacement, maximum

shear forces, and modal participation mass were calculated. The analysis revealed that the first mode shape had the greatest influence, with approximately 88.53% of the shear frame's mass responding to ground motion. A recent study by (Mishra et al., 2022) focused on investigating the response spectrum of a multistorey building located in seismic zone V, characterized as having a high seismic risk or being very severe in India. The research aimed to analyze the building's performance under the influence of earthquakes. The analysis was carried out using STAADPRO software for a G+15 commercial building. The structure's dynamic behavior was analyzed per IS: 1893: 2016 (Part I) for seismic design. It was found that buildings like this are well-suited to withstand small earthquakes with moderate magnitudes and intensities. Researchers in this field also chose different buildings, analyzed them and evaluated their performance such as (Kude, 2020) (Thant & Kyaw, 2019) (Thant & Kyaw, 2019) (Dash, 2015) (Najam & Warnitchai, 2018).
This research aims to present a study to evaluate a 15-storey residential building by calculating the base shear value and story drift, knowing whether the structure is safe using the response spectrum analysis method, and explaining all the steps based on the ETABS program.

2 Methodology of study

This research will outline the various steps involved in assessing building performance through the response spectrum method.

2.1 Response spectrum analysis

Response spectrum analysis is an important method in the structural engineer's toolkit by which engineers can estimate the likely maximum response of a structure to specified base motions or forces, primarily earthquake ground motions. Though it is approximate, it is highly appreciated as the most effective and cost-efficient technique during the early design stages. Several key elements are involved in analyzing the response spectrum: a model for the particular building, mass source, and earthquake in X direction and Y directions should first be known, which is considered the key for response spectrum analysis. These parameters are site class, seismic design category, and spectral acceleration.

2.2 Determination of soil site class and seismic design category

The site class is calculated based on the SPT-N values derived from the soil reports, numbered 150, where SPT-N was extracted for 250 boreholes. Figure 1 shows the borehole distribution. The SPT-N values are entered in the Table that exists in the ASCE/SEI7-16 code, and the Soil Site Class (SSC) is determined from it. The derived SSC represents the soil site class for boreholes only. In order to calculate SSC for all of Iraq, the site class data tables are called into the GIS 10.8 software to draw the SSC interpolation maps, which represent all of Iraq, as shown in Figure 2. The calculated SSC value will unconditionally be adopted and entered into the tables on the ASCE/SEI7-16 code to reach the Seismic Design Category (SDC) value. SDC was presented as an interpolation map, as illustrated in Figure 3. The seismic design value depends on the type of structure (Risk category as defined in ASCE/SEI7-16). Moreover, the structure that was adopted is a residential structure and is within the coordinates (34.19205N, 45.12537E), so it is within the seismic design D. Figure 4 illustrates the steps for calculating SSC and SDC, while Table 1 explains the definition of all parameters related to site class and seismic design category.

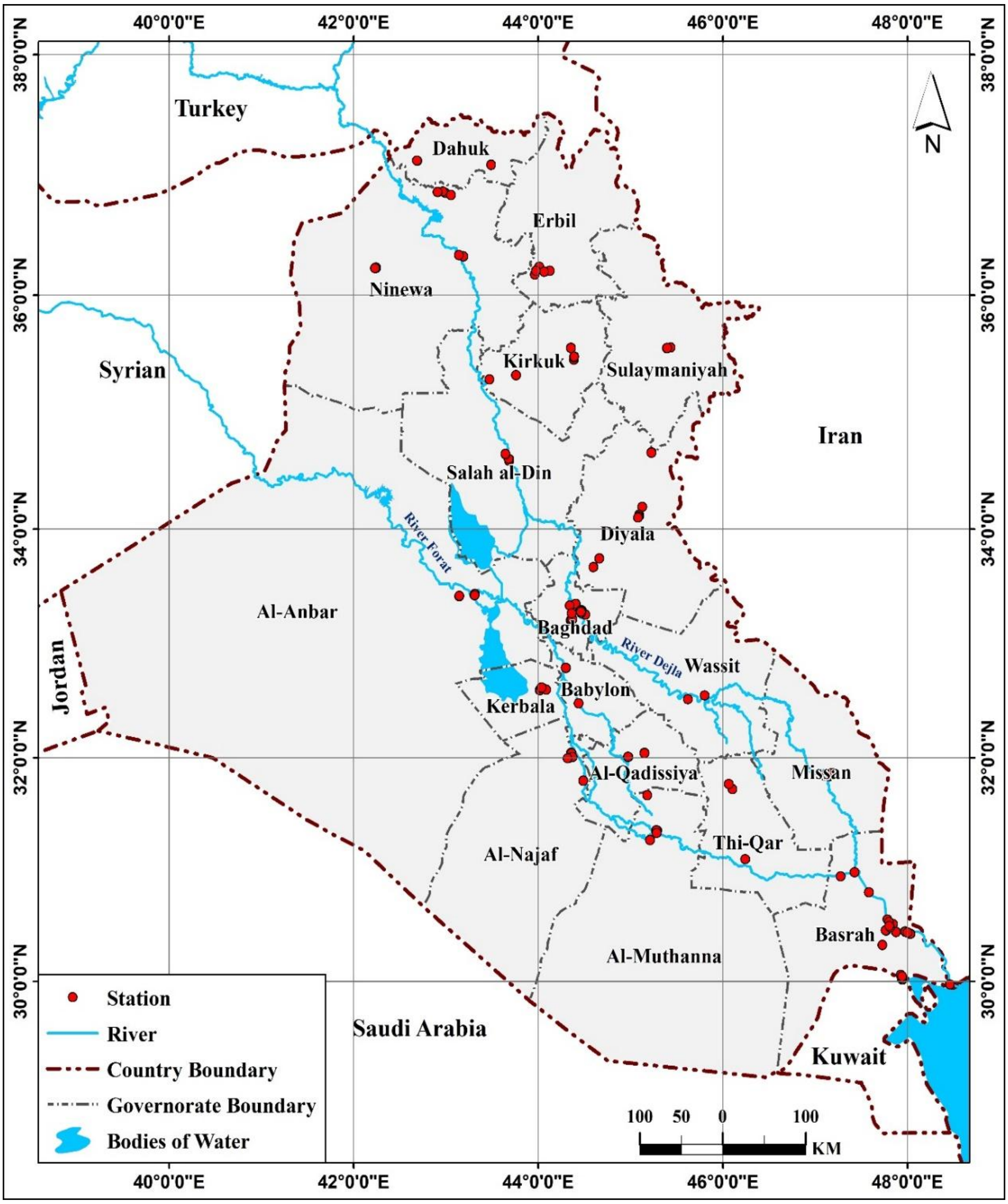


Figure 1: Borehole distribution

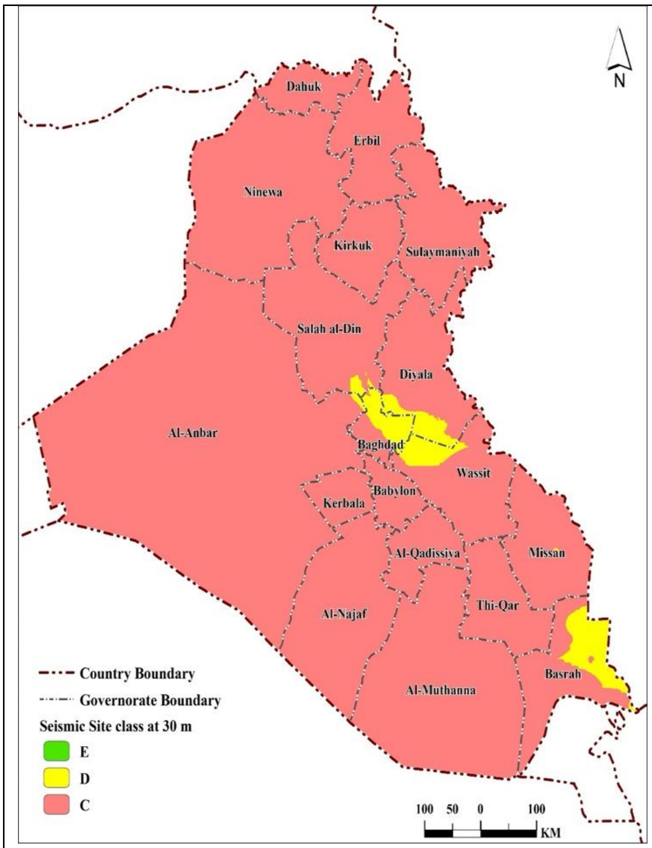


Figure 2: Soil site class for Iraq

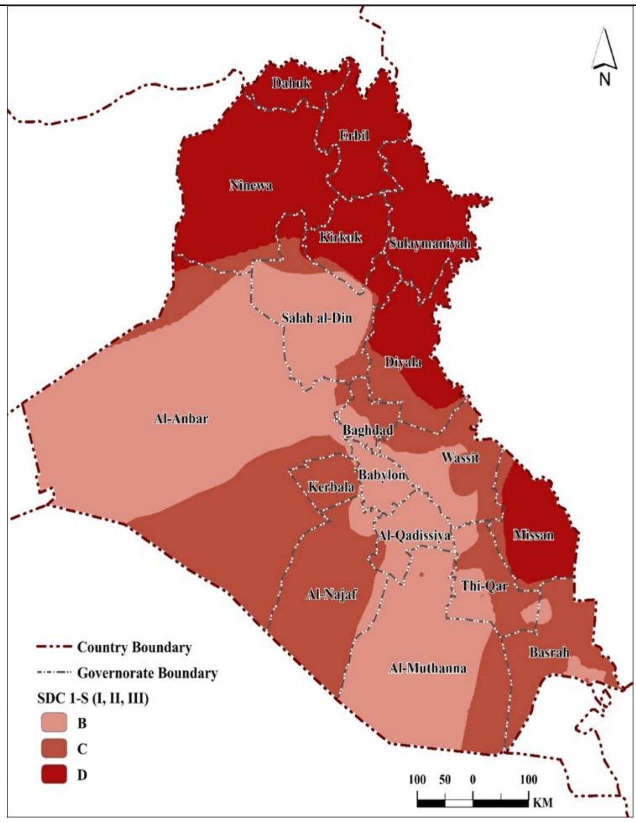


Figure 3: Seismic design category

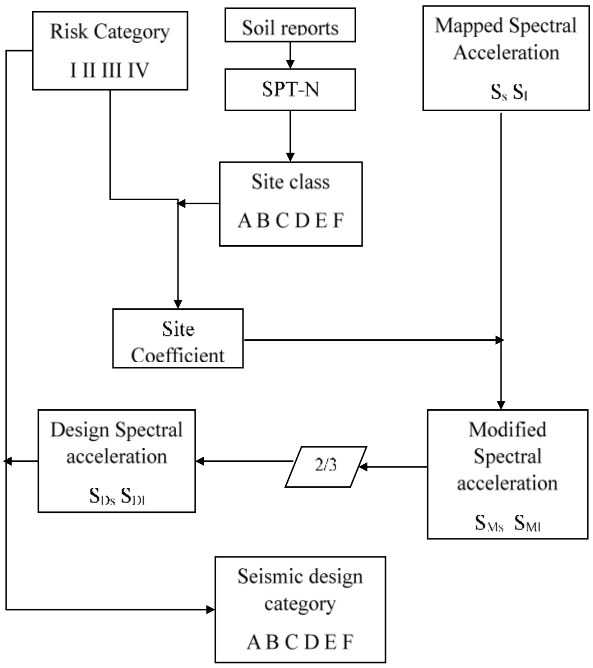


Figure 4:Steps for calculating SSC and SDC

Table 1:Definitions of variables related to SDC

Parameter	Definition	Located in the code
Mapped Spectral Acceleration S_s S_l	A parameter used to characterize the anticipated earthquake shaking at a given site	Two maps in Iraqi code
Risk Category	A categorization of buildings and other structures for determination of flood, wind, snow, ice, and earthquake loads based on the risk associated with unacceptable performance	ASCE/Table 1.5-1
Site class	categorizes sites according to soil properties as Site Class A through F	ASCE/Table (20.3-1)
Site Coefficient Fa, Fv	Parameter used to include soil effect	ASCE/Table 11.4-1 ASCE/Table 11.4-2
Modified Spectral acceleration S_{Ms} S_{Ml}	$S_{MS} = F_a*S_S$ $S_{Ml} = F_v*S_l$	-
Design Spectral acceleration S_{Ds} S_{Dl}	$S_{Ds} = 2/3 *SM_S$ $S_{Dl} = 2/3 *SM_l$	-
Seismic design category	A classification assigned to a structure based on its Risk Category and the severity of the design earthquake ground motion at the site	ASCE/Table 11.6-1 ASCE/Table 11.6-2

2.3 Modeling of structure

A hypothetical structure has been considered in the study and analyses of the response spectrum. This building does not exist at the site, but it was imagined to be at the coordinates (34.19205, 45.12537) in Khanaqin City, Diyala Governorate. The three-dimensional representation of the basement and (G+14) stories of the building measuring 32.20 m * 30.70 m were developed using ETABS 21 software. The building consists of a parking garage and 15 residential stories. Figure 5 shows the three-dimensional model of the building. The building is constructed as a skeleton structure of reinforced concrete flat slabs, beams, columns, shear walls, and a core. Shallow foundations are provided in the form of a raft foundation system. Plain concrete of building with characteristic standard cube strength of fc` 15MPa day of casting and maximum aggregate size for plain concrete equal to 30mm. Dead loads for the flooring and wall of the building were designed to be 1.5 kN/m2 and 2.5 kN/m2, respectively. For the Garges and repeated floors, live loads were determined to be 5 kN/m2 and 2.5 kN/m2. Seismic loads were calculated as outlined in ASCE/SEI 7-16. Table 2 shows the details of the building.
Table 2 contains the value of the reduction factor (R=4), which was adopted according to the ASCE/SEI7-16 code, depending on the type of building, as it was Skelton type, and also contains the values of the spectral acceleration (Ss=0.8, Sl=0.2), which were taken from Figure 6 and Figure 7.

Table 2: Details of building

Materials properties	
Compressive Strength fc`	45 MPa
Density	25 kN/m^3
Young's Modulus Ec	31528 MPa
Poisson's ratio	0.2
Coefficient of thermal expansion	1*10^{-5}
Yield stress fy	400 MPa
Density	78.5 kN/m^3
Modulus of Elasticity Es	210 GPa
Number of stories	G+14
Hight of building	50.2 m
Plan area	32.20 m * 30.70 m
Beam size	(300*700) mm
Seismic properties	
Importance factor (I)	1
Response modification factor (R)	4
Damping ratio	5 %
Soil site class	C
Deflection amplification factor (C_d)	4.5
Mapped spectral acceleration for short and long periods	S_s = o.8, S_l = 0.2

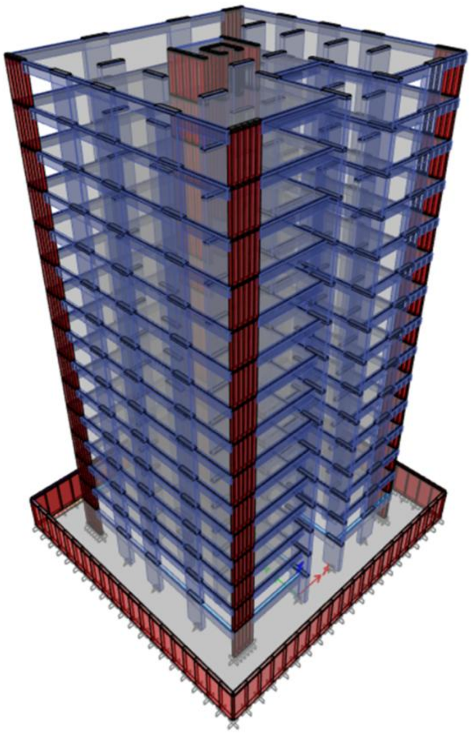


Figure 5: 3D modeling of a building

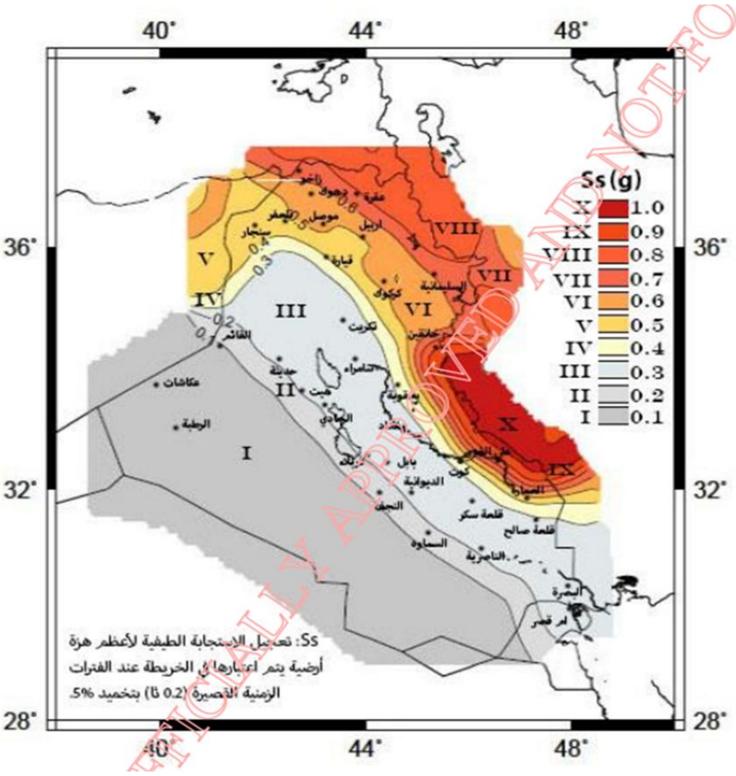


Figure 6: Response Spectral acceleration parameter for shorter periods (After Iraqi code,2017)

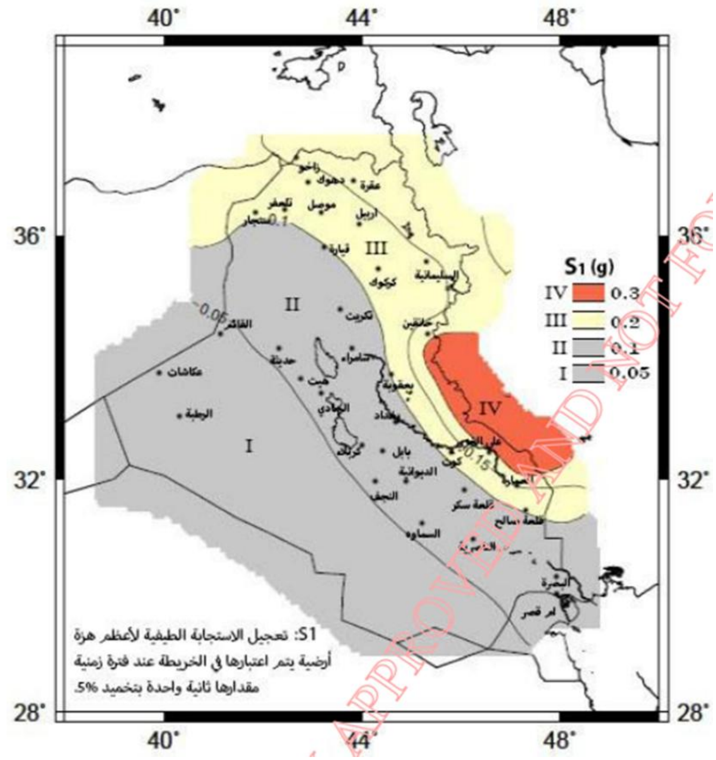


Figure 7:Response Spectral acceleration parameter for longer periods (After Iraqi code,2017)

2.4 Mass source and response spectrum function

The mass source in the ETABS model or effective seismic weight is all mass that contributes to base shear and other member forces in the seismic case. Typically, this is reduced per practical codes as it is far less probable that all floors are occupied during an earthquake. Seismic weight for building purposes was already discussed, and it was stated that 25% of the live load should be taken with all dead load (ASCE/SEI 7-16). For this study, the definition of the mass source in ETABS software uses the aforementioned 25% for the live load. On the other hand, the Response Spectral Function can be defined by going to the defined menu and selecting a function; the second step is choosing the Response Spectral option. It involves inputting earthquake data for the specified area (S_S, S_L), which are 0.8 and 0.2, respectively, from maps existing in Iraqi code, as illustrated in Figure 8.
The response spectrum for the x and y directions is taken as RSX and RSY, respectively. According to the ASCE/SEI 7-16, an analysis shall be made to determine the structure's natural vibration modes. The modes involved in the analysis shall be adequate to ensure that the combined modal mass participation in each orthogonal horizontal direction of response adds up to not less than 90% of the actual mass in the model. The different mode values for each parameter of interest shall then be combined using either the square root of the sum of the squares (SRSS) method, the complete quadratic combination (CQC) method, the CQC method as modified by ASCE 4 (CQC-4) or approved equivalent. The CQC method is referenced in the Figure 9 and Figure 10 Figure 11 in this work.

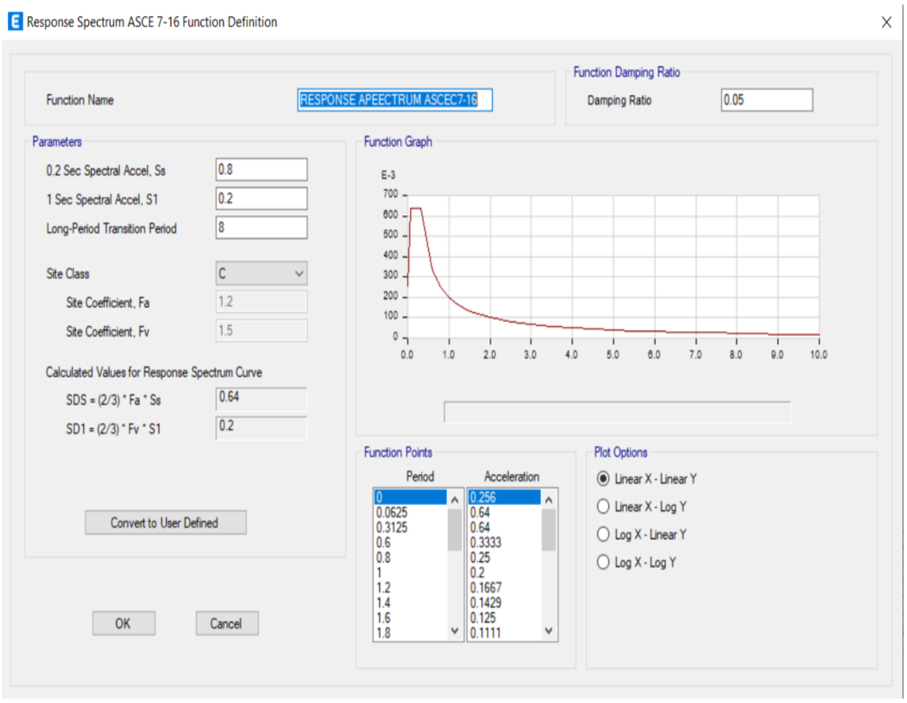


Figure 8: Defining response spectrum function

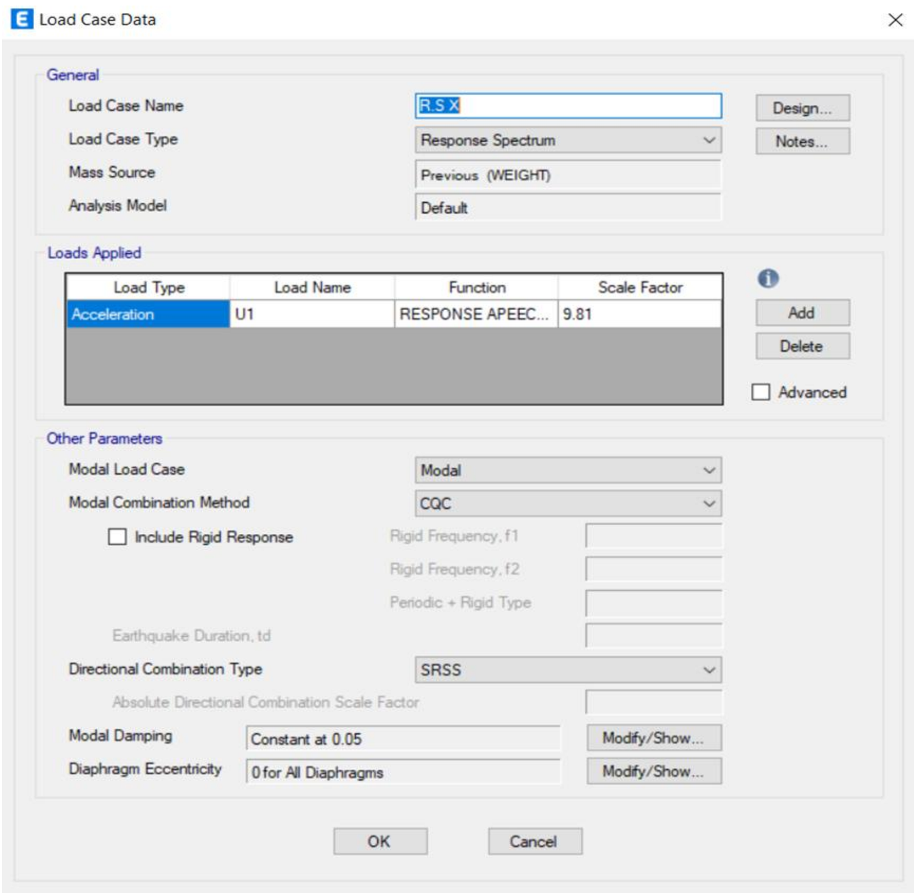


Figure 9:Defining response spectrum in X-Direction

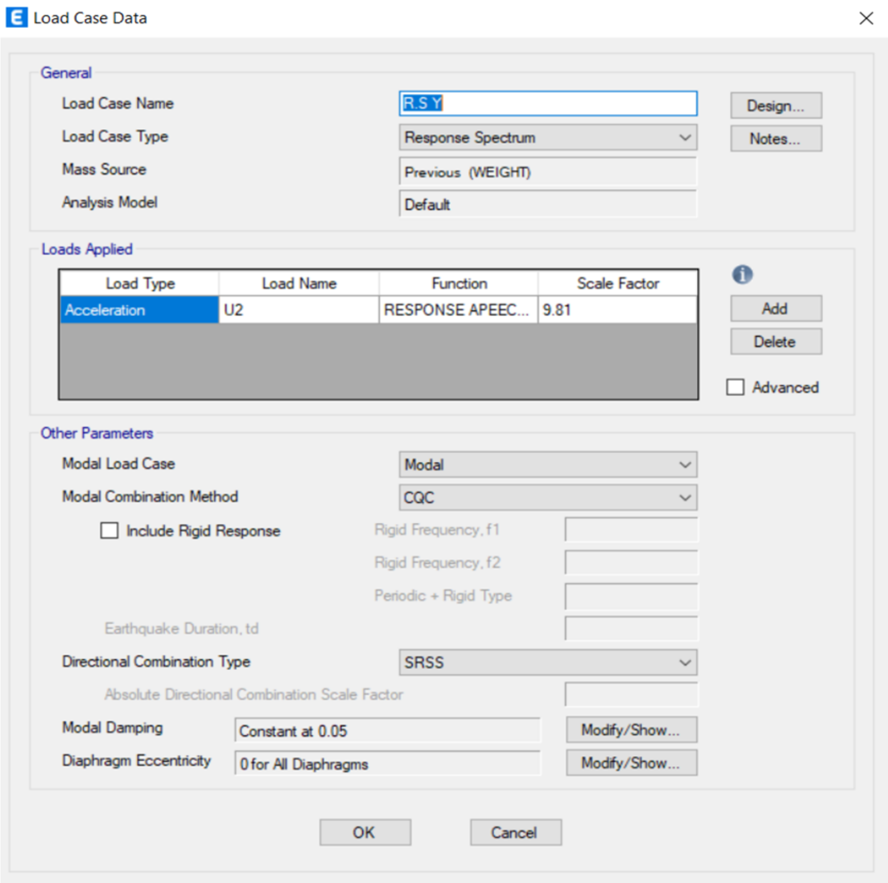


Figure 10: Defining response spectrum in Y-Direction

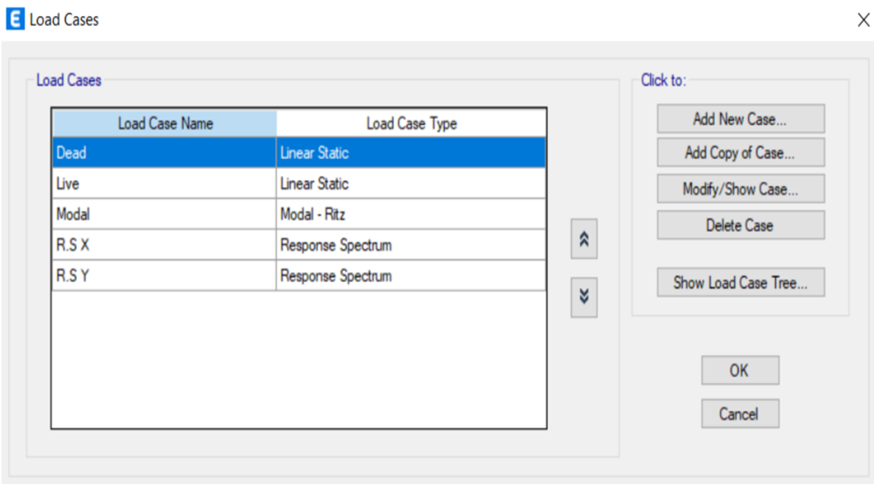


Figure 11: Load cases definition

3 Results

The study adopted modal analysis to derive the dynamic properties of building vibration modes. Key to the analysis was the evaluation of the modal periods, modal masses at floor levels, center of mass and center of rigidity at each floor level, story drift and base shear for a time history analysis. The modal Ritz method addressed the nonlinear responses due to gravity loads and geometric nonlinearity (P-Δ). This work, 30 modes were used, which collectively involve about 100% mass of the building in the mode shapes. According to (ASCE/SEI 7-16), good practice is that the modes that constitute at least 90% of the mass in the building in the mode shapes should be a minimum.

3.1 Model participating mass ratio

A sufficient number of modes (30 modes) were considered to ensure that approximately 100% of the building mass was accounted for in the mode shapes. However, according to (ASCE/SEI 7-16), it is recommended that a minimum number of modes should encompass at least 90% of the building mass in the mode shapes. Table 3 outlines the building model's modal characteristics.

Table 3: Model participating mass ratio

TABLE: Modal Participating Mass Ratios														
Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
		sec												
Modal	1	2.527	0.66	0.0002	0	0.66	0.0002	0	0.0001	0.3615	0.0046	0.0001	0.3615	0.0046
Modal	2	2.288	0.0007	0.6598	0	0.6607	0.66	0	0.3495	0.0004	0.0132	0.3496	0.3619	0.0178
Modal	3	1.991	0.0063	0.0153	0	0.667	0.6753	0	0.007	0.004	0.6214	0.3566	0.3659	0.6392
Modal	4	0.716	0.1094	0.0001	0	0.7764	0.6754	0	0.0001	0.2323	0.0021	0.3567	0.5982	0.6414
Modal	5	0.66	0.0002	0.1061	0	0.7766	0.7815	0	0.2492	0.0004	0.0013	0.606	0.5987	0.6427
Modal	6	0.604	0.0039	0.001	0	0.7806	0.7825	0	0.0037	0.0079	0.0837	0.6096	0.6066	0.7264
Modal	7	0.352	0.0386	0	0	0.8192	0.7825	0	0	0.0438	0.0048	0.6096	0.6504	0.7312
Modal	8	0.326	6.384E-06	0.0461	0	0.8192	0.8286	0	0.0508	6.684E-06	1.569E-06	0.6604	0.6504	0.7312
Modal	9	0.313	0.0076	2.496E-05	0	0.8267	0.8287	0	0.0001	0.0087	0.0317	0.6605	0.6591	0.7629
Modal	10	0.214	0.0189	0.0000368	0	0.8456	0.8287	0	0.0001	0.0342	0.0066	0.6606	0.6933	0.7694
Modal	11	0.195	0.0008	0.0273	0	0.8464	0.856	0	0.0507	0.0014	0.0006	0.7113	0.6948	0.77
Modal	12	0.191	0.0088	0.0017	0	0.8553	0.8576	0	0.0029	0.0159	0.0145	0.7142	0.7106	0.7846
Modal	13	0.143	0.0115	0.0001	0	0.8668	0.8577	0	0.0001	0.0192	0.0064	0.7143	0.7299	0.7909
Modal	14	0.13	0.0022	0.0176	0	0.869	0.8753	0	0.0296	0.0037	0.0011	0.7439	0.7336	0.792
Modal	15	0.128	0.0074	0.0038	0	0.8763	0.8791	0	0.0065	0.0125	0.0073	0.7505	0.7461	0.7994
Modal	16	0.103	0.0091	0.0001	0	0.8854	0.8792	0	0.0002	0.0175	0.0057	0.7506	0.7636	0.8051
Modal	17	0.094	0.0023	0.0152	0	0.8877	0.8944	0	0.0297	0.0044	0.0007	0.7803	0.768	0.8057
Modal	18	0.092	0.0073	0.0036	0	0.895	0.898	0	0.007	0.0141	0.0045	0.7873	0.7821	0.8102
Modal	19	0.078	0.0107	0.0001	0	0.9057	0.8981	0	0.0001	0.0205	0.0032	0.7875	0.8026	0.8134
Modal	20	0.072	0.0007	0.0185	0	0.9064	0.9167	0	0.036	0.0013	0.00002068	0.8235	0.8039	0.8134
Modal	21	0.067	0.0148	0.001	0	0.9211	0.9176	0	0.002	0.0293	0.0006	0.8255	0.8332	0.814
Modal	22	0.058	0.0026	0.0203	0	0.9237	0.938	0	0.0419	0.0054	0.0001	0.8674	0.8386	0.8141
Modal	23	0.056	0.0275	0.0027	0	0.9512	0.9407	0	0.0057	0.0568	0.0012	0.8731	0.8954	0.8153
Modal	24	0.049	0.0023	0.0247	0	0.9536	0.9654	0	0.0517	0.0049	0.0001	0.9248	0.9003	0.8154
Modal	25	0.046	0.0342	0.0027	0	0.9878	0.9681	0	0.0058	0.0727	0.0044	0.9306	0.9729	0.8199
Modal	26	0.042	0.0017	0.0224	0	0.9894	0.9905	0	0.0483	0.0036	0.0001	0.9789	0.9765	0.82
Modal	27	0.036	0.0078	0.0031	0	0.9973	0.9936	0	0.0069	0.0174	0.0009	0.9858	0.994	0.8209
Modal	28	0.035	0.0022	0.0059	0	0.9995	0.9995	0	0.0131	0.0049	0.0006	0.9989	0.9988	0.8215
Modal	29	0.018	0.0003	0.0001	0	0.9998	0.9997	0	0.0003	0.0007	0.0141	0.9992	0.9995	0.8356
Modal	30	0.015	0.0001	0.0003	0	0.9999	0.9999	0	0.0006	0.0003	0.0076	0.9998	0.9998	0.8432

3.2 Center of mass and center of rigidity

According to the ASCE/SEI 7-16 code, there is a requirement that the disparity between the center of mass and the center of rigidity must not surpass 15% of the length and width. The center of mass and rigidity center are displayed in Table 4.

Table 4: Center of mass and center of rigidity

TABLE: Centers Of Mass And Rigidity											
Story	Diaphragm	Mass X	Mass Y	XCM	YCM	Cum Mass X	Cum Mass Y	XCCM	YCCM	XCR	YCR
		tonf-s²/m	tonf-s²/m	m	m	tonf-s²/m	tonf-s²/m	m	m	m	m
Story1	D1	53.9891	53.9891	2.9108	11.0374	53.98905	53.98905	2.9108	11.0374	2.7435	11.1134
Story2	D2	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.6711	12.4406
Story3	D3	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.7252	12.4886
Story4	D4	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.7931	12.438
Story5	D5	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.8607	12.373
Story6	D6	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.9261	12.3113
Story7	D7	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	2.9889	12.2583
Story8	D8	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.0496	12.2151
Story9	D9	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.1088	12.181
Story10	D10	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.1672	12.1547
Story11	D11	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.2258	12.1341
Story12	D12	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.2854	12.1168
Story13	D13	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.347	12.0995
Story14	D14	31.3643	31.3643	3.0726	11.0827	31.36432	31.36432	3.0726	11.0827	3.4102	12.0793
Story15	D15	23.4468	23.4468	2.9364	10.9941	23.4468	23.4468	2.9364	10.9941	3.4679	12.0605

According to the data presented in Table 4, the variance between the center of mass and the center of rigidity of each story in the x-direction (lengthwise) is below 15% of the length. Similarly, the discrepancy between the center of mass and the center of rigidity in the y-direction (width) is also less than 15% of the width. These findings align perfectly with the requirements outlined in the ASCE /SEI 7-16 code.

X $< 0.15 \times 32.20 = 4.83$ ok

y $< 0.15 \times 30.70 = 4.60$ ok

3.3 Base shear

The code stipulates that the base shear calculated from the dynamic case must not be less than the value calculated from the static case. The base shear in the static state is calculated through the following equation:

$V_{static} = Cs*W$ (1)

Where: Cs = the seismic response coefficient; W = the effective seismic weight; Cs can be calculated from the following equation

$$Cs = \frac{S_{Ds}}{\frac{R}{Ie}} \quad (2)$$

- S_{Ds} = the design spectral response acceleration parameter in the short period range.
- R = the response modification factor, and I_e = the Importance Factor.

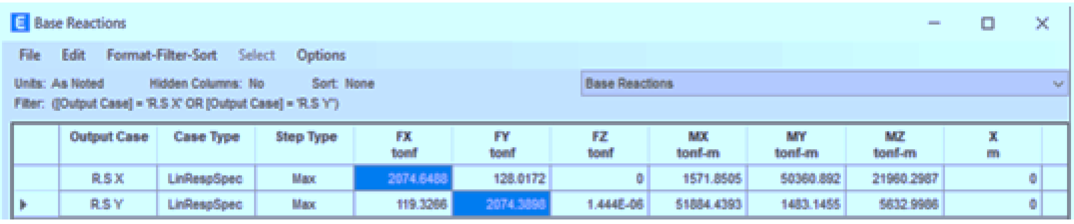
The S_{Ds}, R and Ie, equal 0.64, 4 and 1, respectively. Also, the effective seismic weight equal to 12986 tons (calculated by ETABS software and according to ASCE/SEI 7-16 code) shall include all the dead load above the base and 25% of the live load). So, the base shear in the static case can be computed as shown:

$V_{static} = \frac{0.64}{\frac{4}{1}} * 12986 = 2077$ ton

At the same time, the base shear in the dynamic case will be computed by ETABS (in the dynamic case, the base shear will computed in both X and Y directions), which are equal to 1037 tons (in the X-direction) and 1115 ton (in Y-direction), these values will be compared with the value of base shear in static case. The ASCE/SEI 7-16 code states that if the combined response for the modal base shear ($V_{dynamic}$) is less than 100% of the calculated base shear in static case (V_{static}), the forces shall be multiplied by $V_{static}/V_{dynamic}$ (paragraph 12.9.1.4 in ASCE/SEI7-16 code) so the value of base shear will be as shown:

$V_{dynamic(X)} = \frac{2077}{1037} * 1037 = 2o77$ ton, $\quad V_{dynamic(y)} = \frac{2077}{1115} * 1115 = 2077$ ton.

Figure 12 shows the background from ETABS by which the base shear multiplying by scale factor


Base Reactions
File Edit Format-Filter-Sort Select Options
Units: As Noted Hidden Columns: No Sort: None Base Reactions
Filter: ([Output Case] = 'R.S X' OR [Output Case] = 'R.S Y')

Output Case	Case Type	Step Type	FX tonf	FY tonf	FZ tonf	MX tonf-m	MY tonf-m	MZ tonf-m	X m
R.S X	LinRespSpec	Max	2074.6488	128.0172	0	1571.8505	50360.892	21960.2987	0
R.S Y	LinRespSpec	Max	119.3266	2074.3898	1.444E-06	51884.4393	1483.1455	5632.9986	0

Figure 12: Base shear reactions

3.4 Story drift

In the ASCE/SEI 7-16 code, the story drift is defined as the horizontal displacement at the top of the story in relation to the bottom. When using the response spectrum, the base shear value is adjusted by dividing it by the factor R to obtain the base shear for inelastic cases. Simultaneously, the displacement value corresponding to this shear is determined for elastic cases, as shown in Figure 13. Consequently, the code increases this value by multiplying the displacement by the deflection amplification factor. To calculate the final displacement value, the following equation is used:

$$\delta x = \frac{Cd * \delta xe}{Ie} \tag{3}$$

Where: δ_x = The deflection at level x; C_d= deflection amplification factor; δ_{xe}= deflection at the location required for the elastic case; and I_e= Importance Factor.

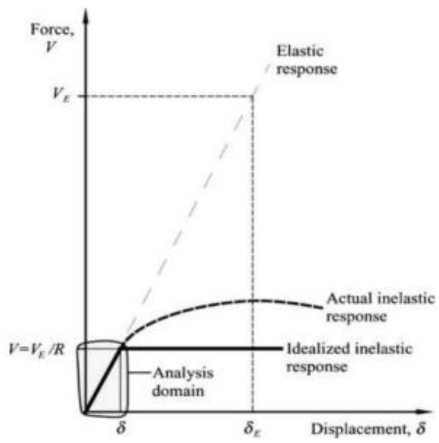


Figure 13: Displacement used to calculate drift

In response to spectrum analysis for the 3D building model, ETABS software calculates the stories drifts. Figure 14 shows the maximum story drift, which appears at story 6 with a value of 0. 010647. this maximum value of drift is for elastic case, and it will convert to inelastic depending on equation (3)

$$\Delta_{inelastic} = \frac{0.010647*4.5}{1} = 0.0479115$$

The building being examined is a residential building categorized as "other structures" in terms of allowable drift values. Specifically, it falls under risk category I or II according to the provided Table 5. As per this classification, the allowable drift value is 0.020. However, the analysis using the response spectrum acceleration method yielded a drift value of 0.0479. Consequently, the calculated drift is approximately two and a half times higher than the allowable drift.

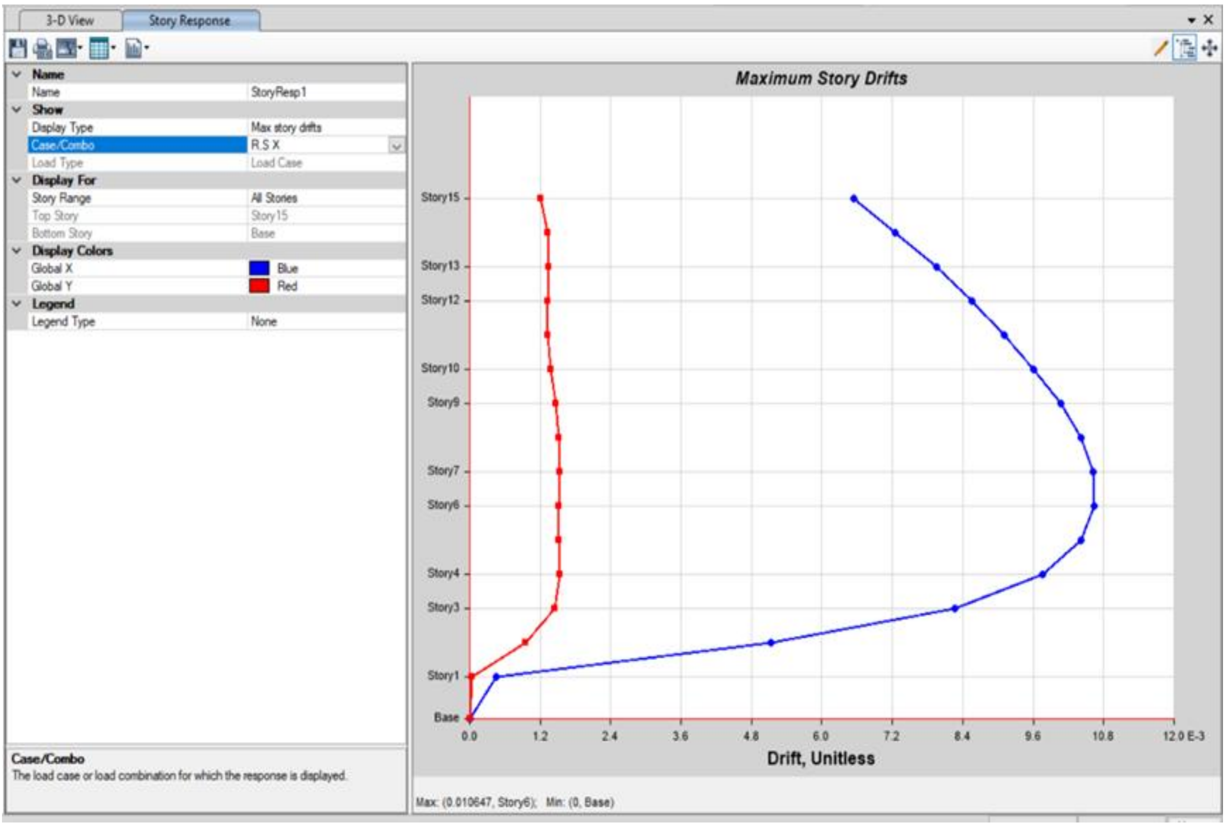


Figure 14: Maximum story drift

Table 5: Allowable Story Drift (After ASCE/SEI7-16)

	Risk Category		
Structures	I or II	III	IV
Structures, other than masonry shear wall structures, four stories or less above the base, with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

4 Conclusion

This research presented an analysis process for a building consisting of (G+14) stories using the response spectrum analysis method. All the required verifications were done to complete the analysis process, where the center of mass and rigidity were calculated, and the values were within the permissible limit. Also, 30 mode shapes were taken to reach a mass participation ratio contributing to the structure movement of 90% or more, as stated in the ASCE/SEI7-16 code. Calculating the base shear and story drift was the main objective of the research. The results showed that the structure was unsafe because the story drift exceeded the permissible limit by two and a half times. The reason for this high value of drift is the value of the spectral acceleration that was used in this research, which was taken from the spectral acceleration map found in the Iraqi code, where the value reached (Ss=0.8), which is the highest value found in the map and represents the area near the Iraqi-Iranian border, as this value gives a high earthquake value so the drift value is exceeded the permissible limit, so the structure is considered unsafe.

5 References

Abdi, A. I., & Yaseen, A. A. (2021). Seismic vulnerability assessment of existing RC Multi-story Buildings in Duhok City, Kurdistan region of Iraq. *Journal of Duhok University*, *24*(1), 60–78.

Abdulnaby, W., Mahdi, H., Al-Shukri, H., & Numan, N. M. S. (2014). Stress Patterns in Northern Iraq and Surrounding Regions from Formal Stress Inversion of Earthquake Focal Mechanism Solutions. *Pure and Applied Geophysics*, *171*(9), 2137–2153. https://doi.org/10.1007/s00024-014-0823-x

Al-Dabbagh, H. A. (1999). *Review and analyses of some earthquakes events in Iraq*. M. Sc. thesis, University of Baghdad, p: 116.(Arabic reference).

Al-jassim, S., & Husssain, M. A. (2018). Pushover analysis of G+ 5 Reinforced concrete building in Basrah. *International Journal of Innovations in Engineering and Technology (IJIET), ISSN*, 1058–2319.

Alsinawi, S. A. (2002). Seismicity, seismotectonics, crustal structure and attenuation data on Iraq. *RELEMR Meetings, Antakya, Turkey*.

Alsinawi, S. A., & Al-Qasrani, Z. O. (2003). Earthquake hazards consideration for Iraq. *Fourth International Conference of Earthquake Engineering and Seismology*, *12*, 14.

Alsinawi, S., & Ghalib, H. A. A. (1975). Historical seismicity of Iraq. *Bulletin of the Seismological Society of America*, *65*(2), 541–547. https://doi.org/10.1785/BSSA0650020541

Ameer, A. S., Sharma, M. L., Wason, H. R., & Alsinawi, S. A. (2005). Probabilistic Seismic Hazard Assessment for Iraq Using Complete Earthquake Catalogue Files. *Pure and Applied Geophysics*, *162*(5), 951–966. https://doi.org/10.1007/s00024-004-2650-y

Amer, A.-N., Sobaih, M., & Adel, A. (2016). Investigation of Effects of Capacity Spectrum Method on Performance Evaluation of Multi-Story Buildings According to the IRAQI Seismic Code Requirements. *Open Journal of Civil Engineering*, *06*(03), 420–441. https://doi.org/10.4236/ojce.2016.63036

Anirudh Raajan, V., Balaji, G. C., & Vasavi, V. (2021). Response spectrum analysis of a G+4 building with mass irregularity on a sloped surface. *IOP Conference Series: Materials Science and Engineering*, *1070*(1), 012043. https://doi.org/10.1088/1757-899x/1070/1/012043

Chandak, N. R. (2012). Response Spectrum Analysis of Reinforced Concrete Buildings. *Journal of The Institution of Engineers (India): Series A*, *93*(2), 121–128. https://doi.org/10.1007/s40030-012-0012-9

Choudhary, S. N., & Bokare, P. S. (2018). Dynamic Analysis of Multistory Building Using Response Spectrum Method and Seismic Coefficient Method-A Comparison. *IJISET-International Journal of Innovative Science, Engineering & Technology*.

Dash, S. S. (2015). *Seismic Analysis of High-Rise Building by Response Spectrum Method*.

Hassaballa, A. E., Adam, F. M., & Ismaeil, M. A. (2013). *Seismic analysis of a reinforced concrete building by response spectrum method*.

Hussein, A. (2021). Dynamic Response Spectrum of Multi-Story Shear Frame Subjected to Moderate Ground Motion. *Diyala Journal of Engineering Sciences*, *14*(2), 71–79. https://doi.org/10.24237/djes.2021.14207

Issa, A.A., 1983. Seismicity and Seismotectonics of Iraq, M.Sc. thesis, University of Baghdad,142p, unpublished.

(Arabic reference).

Kamranzad, F., Memarian, H., & Zare, M. (2020). Earthquake Risk Assessment for Tehran, Iran. *ISPRS International Journal of Geo-Information*, *9*(7), 430. https://doi.org/10.3390/ijgi9070430

Kude, M. D. (2020). Influence of Zone Factor on Seismic Performance of Multi-Storied RCC Frame using ETABS 2016. *International Journal for Research in Applied Science and Engineering Technology*, *8*(5), 1758–1767. https://doi.org/10.22214/ijraset.2020.5284

Mishra, A., Yadav, M., & Vanshaj, K. (2022). *RESPONSE SPECTRUM ANALYSIS OF A MULTISTOREY BUILDING IN SEISMIC ZONE – V*. *4*(03), 1903–1910.

Najam, F. A., & Warnitchai, P. (2018). A modified response spectrum analysis procedure to determine nonlinear seismic demands of high-rise buildings with shear walls. *The Structural Design of Tall and Special Buildings*, *27*(1). https://doi.org/10.1002/tal.1409

S. R. Kangle. (2020). Response Spectrum Analysis for Regular Multistory Structure in Seismic Zone III. *International Journal of Engineering Research And*, *V9*(09). https://doi.org/10.17577/IJERTV9IS090262

Said, A. I., & Farman, M. S. (2018). Re-evaluations of seismic hazard of Iraq. *Arabian Journal of Geosciences*, *11*(11), 1–19. https://doi.org/10.1007/s12517-018-3558-7

Sharma, M., & Maru, D. S. (2014). Dynamic analysis of multistoried regular building. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN*, 1684–2278.

Shearer, P. M. (2009). *Introduction to Seismology*. Cambridge University Press. https://doi.org/10.1017/CBO9780511841552

Soni D. K., Ashwani J. and Harshdeep (2012), " Earthquake and Mitigations", International Journal of Applied Engineering Research, ISSN 0973-4562 Vol 7 No.11

Thant, N. N., & Kyaw, T. Y. (2019). Study on the Effect of Response Spectrum Analysis and Construction Sequence Analysis on Setback Steel Structure. *Publ Int J Trend Sci Res Dev*, *3*(4), 1349–1355.

Wang, Y. J. et al. (2016) "Probabilistic seismic hazard assessment for iraq," Terrestrial, Atmospheric and Oceanic Sciences, 27(3), pp. 325–340

Y. Ahmed, S. (2013). Seismic Evaluation of Reinforced Concrete Frames Using Pushover Analysis(eng). *Al-Rafidain Engineering Journal (AREJ)*, *21*(3), 28–45. https://doi.org/10.33899/rengj.2013.75445

Yaseen, Z. A. A. O. T. A. A. (2020). Seismic Vulnerability Assessment of Reinforced Concrete Building Structures in Erbil City, Capital City of Kurdistan Region of Iraq. *Eurasian Journal of Science and Engineering*, *6*(1). https://doi.org/10.23918/eajse.v6i1p161