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# Seismic Response Spectrum Curves for Selected Cities in Libya

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**Abstract-The probabilistic seismic hazard analysis (PSHA) is required for the seismic resistance design of structures in order to determine the seismic hazard parameters at the site. Based on these parameters, international codes of practice such as the International Building Code (IBC) and ASCE-7 Standard provide design procedures and methods for seismic-resistant building design. Equivalent lateral force (ELF) procedure, Response Spectrum Analysis (RSA), and Time History Analysis (THA) are the three most commonly used linear seismic design methods for buildings. These procedures rely on design response spectra curves derived from PSHA output... Ngab et al. [1] recently performed a seismic hazard analysis for Libya which included mapping seismic parameters for the Maximum Considered Earthquake (MCE) with a 2% probability of exceedance in 50 years, a return period of 2475 years, soil site class B, and a damping ratio of 5% for time-periods of 0.2s and 1.0s.**

**This paper presents the results of constructing response spectra curves for 18 cities in Libya based on this mapped data in accordance with ASCE-7 recommendations, and soil site classifications C and D for Design Basis Earthquake (DBE). The response spectra curves for the selected cities are graphical representations of the cities' seismic responses to various levels of ground shaking. The curves depict the maximum spectral acceleration that can be expected from future earthquakes at various time intervals that a structure may encounter during an earthquake. These curves are used to assist engineers in designing structures that can withstand earthquake forces. They also serve as a foundation for assessing the seismic risk of a structure in a specific location. These forces can be used directly in conjunction with design codes to calculate seismic hazard levels in order to ensure safe and cost-effective construction as required by all codes.**

**Key words; Seismic hazard, response spectrum, design basis earthquake, equivalent lateral force procedure, time history analysis.**

## I INTRODUCTION

Response spectrum curves are important in seismic design of buildings because they provide a way to assess the seismic response of a structure to ground motion. These curves as defined by seismic codes is a graphical representation of the maximum spectral acceleration that a structure may experience during an earthquake. By comparing the response of different structures, engineers can determine which structure is best suited for a particular seismic hazard. Buildings can be designed to withstand future earthquakes and reduce the risk of damage or collapse. Response spectrum curves can also help engineers to determine the appropriate design parameters for buildings, such as its height, mass and stiffness. The response spectrum curves are also an essential input in the design procedures for seismic resistant structures. To calculate the effects of earthquakes on structures, three seismic analysis procedures can be used. One method is the equivalent lateral load procedure (ELF), which represents the seismicity of the earthquake by directly using Ss and $S_1$ seismic parameters for our site. This method is based on the idea that we calculate some equivalent lateral (static forces) that will be reprehensible in the event of a future earthquake and then apply these forces to the computer linear model. The magnitude of these forces will be determined by the level of seismic hazard at the site, as defined by the seismic parameters Ss and S1. The response spectrum analysis is the second method, and in this method, the future earthquake is not represented by Ss and $S_1$ only, but it is represented by the complete response spectrum of the future earthquake, which is a graph between spectral acceleration and time period of the structure This method requires the entire curve as an input of seismic loadings. And in this case, there are two approaches: one in which we consider code equations to construct this future response spectrum curve, and another in which we perform detailed seismic site specific seismic hazard analysis and construct these curves for our site to plot the response spectrum. Code equations use the seismic parameters Ss and $S_1$ to construct the complete RSA curves for a specific site with a specified damping ratio and soil class. Time history analysis is the third technique. This is a rigorous dynamic analysis procedure that necessitates the complete time history of the earthquake, which corresponds to the code linear model in dynamic movement. The other two methods are essentially static in nature, as they are based on the application of static forces to the structure's computer model as a representative of future earthquake ground shakings. Because the static forces applied to the structure model are calculated based on the building's mode shapes and time period of the modal, the response spectrum procedure can be considered pseudo-dynamic. The seismicity of Libya has been investigated by several researchers. A recent study of the seismic hazard analysis has shown that Libya can be classified as a low-to-moderate seismic hazard region. The northern part of the country showed significant seismic activity compared with the Southern Sahara region around Sabha. The Spectral Acceleration (Ss) and the Spectral Acceleration (S1) ranged from maximum values of 0.64, and 0.12 in Abugrin-Algidaahia in the North to 0.0 in Sabha in the Southern region, respectively. However, Al Joufra, which is located in the Mid-South, showed moderate seismic activity with Ss= 0.39 and S1 = 0.10. These seismic hazard parameters, were modified to reflect soil site classifications C, and D to construct the design response spectra for the selected cities with significant seismic hazard around the country. These curves can easily be used to for the anticipated future earthquakes as required by international codes. Design Basis Earthquake (DBE) which is 2/3 of the Maximum Considered Earthquake (MCE) with a probability of exceedance (PE) of 2% in 50 years and a return period of 2475 in accordance with the IBC design code and ASCE-7 standard. Table 1 below summarizes the seismic Hazard Parameters, Maximum Considered Earthquake (MCE), PE 2% in 50 yrs., Return Period 2475 yrs.[ 1,2,3,4]. Figure 1. Shows the seismic intensity maps for the Northern zones of Libya.

Table 1: Seismic Hazard Parameters, (MCE), PE 2% in 50 years, and Return Period 2475 years.[1]

| City | PGA (g) | $S_s$ (g) | $S_1$ (g) |
|---|---|---|---|
| Tripoli airport | 0.14 | 0.28 | 0.04 |
| Tripoli Harbor | 0.15 | 0.32 | 0.05 |
| Az zawiyah | 0.12 | 0.23 | 0.03 |
| Zuwarah | 0.10 | 0.20 | 0.03 |
| Gharyan | 0.06 | 0.11 | 0.02 |
| Nalut | 0.00 | 0.00 | 0.00 |
| Ghadamis | 0.00 | 0.00 | 0.00 |
| Al khums | 0.14 | 0.30 | 0.05 |
| Zliten | 0.14 | 0.20 | 0.04 |
| Misratah | 0.09 | 0.18 | 0.04 |
| Sirt | 0.16 | 0.33 | 0.06 |
| Ajdabiya | 0.00 | 0.00 | 0.00 |

| City | PGA (g) | $S_s$ (g) | $S_1$ (g) |
|---|---|---|---|
| Banghazi | 0.12 | 0.22 | 0.03 |
| Al marj | 0.21 | 0.44 | 0.06 |
| Shahat | 0.20 | 0.42 | 0.06 |
| Darnah | 0.19 | 0.39 | 0.06 |
| Al jabal akhdar | 0.06 | 0.13 | 0.02 |
| Al jaghbub | 0.00 | 0.00 | 0.00 |
| Al kufrah | 0.00 | 0.00 | 0.00 |
| Sabha | 0.00 | 0.00 | 0.00 |
| Al joufrah | 0.15 | 0.39 | 0.10 |
| Hun | 0.04 | 0.10 | 0.03 |
| Abunjim | 0.20 | 0.49 | 0.13 |
| Abugrin-Algidaahia | 0.28 | 0.64 | 0.12 |



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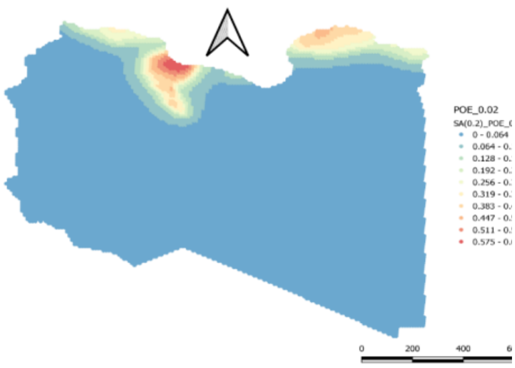


Figure 1: Seismic Hazard Parameters Ss and $S_1$, Maximum Considered Earthquake (MCE) Maps PE 2% in 50 years, Return Period 2475 years. (SHA-The Classical Method)

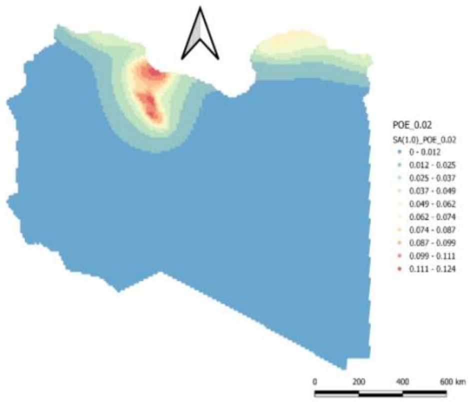


Figure 2. is the ASCE-7 Standard response spectrum curve.

## II .CONSTRUCTION OF DESIGN RESPONSE SPECTRA CURVES

In the “old” code (ASCE-7-5,IBC-2009), ground motions were developed using a uniform hazard approach where the Maximum Considered Earthquake (MCE) corresponds to a return period of 2475 years and 2% PE in 50 years and a uniform reduction corresponding to 2/3 of the MCE to the Design Basis Earthquake (DBE). The "New" code (ASCE-7-16, IBC-2019, ground motions) is developed using a more complex risk-targeted or performance-based approach that considers a uniform probability of structural collapse of 1% rather than the previous codes' probability of MCE exceedance of 2%. Thus, unlike the old code, which focused on the likelihood of ground motions occurring (Seismic-hazard), the new code focuses on the likelihood of structure collapse ( Risk-targeted approach). The new SDs and SD1, respectively, design spectral accelerations at 0.2s and 1.0s, corresponding to the Mapped risk targeted maximum considered earthquake ($MCE_R$), which corresponds to a 1% chance of building collapse. We are only concerned with the provisions and approaches of the old code in this study. $MCE_R$=$C_R$ MCE, where $C_R$ is a risk coefficient ranging between 0.70 and 1.3. It is essential to determine the seismic parameters Ss and $S_1$ for site class B with a damping ratio of 5% for the specific site. The recent (2022) study on Seismic Hazard Analysis for Libya by Ngab et al [1] included mapping of seismic parameters for the Maximum Considered Earthquake (MCE). [5,6,7]. The procedure for creating Response Spectrum curves is summarized below. The parameters $S_S$ and $S_1$ represent the MCE, 5%-damped, spectral acceleration parameters at short period 0.2s, and 1s period. $S_S$= the mapped MCE spectral response acceleration parameter at short periods, and where, $S_1$= the mapped MCE spectral response acceleration parameter at a period of 1s.

$$S_{DS} = \frac{2}{3} S_{MS} \qquad S_{D1} = \frac{2}{3} S_{M1} \qquad (1)$$

$$T_0 = 0.2(\frac{S_{D1}}{S_{DS}}).\ T_S = \frac{S_{D1}}{S_{DS}}.\ \text{and } T_L = \text{Long period.} \qquad (2)$$

$$.T < T_0 \rightarrow Sa = S_{DS}(0.4 + 0.6\frac{T}{T_0}) \qquad (3)$$

$$T \geq T_0 < T_S \rightarrow S_a = S_{DS} \qquad (4)$$

$$T > T_S \leq T_L \rightarrow Sa = \frac{S_{D1}}{T} \qquad (5)$$

$$T > T_L \rightarrow Sa = \frac{S_{D1}T_L}{T^2} \qquad (6)$$

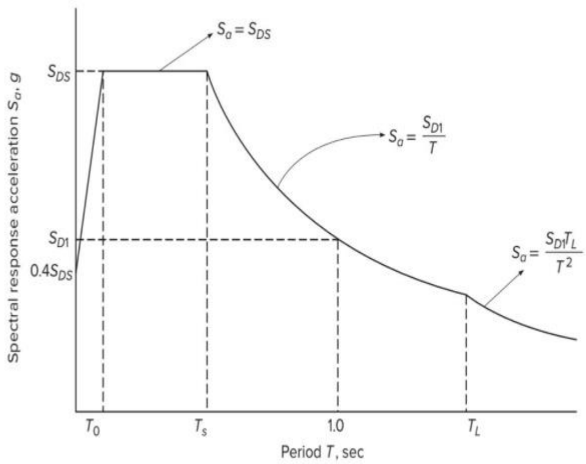
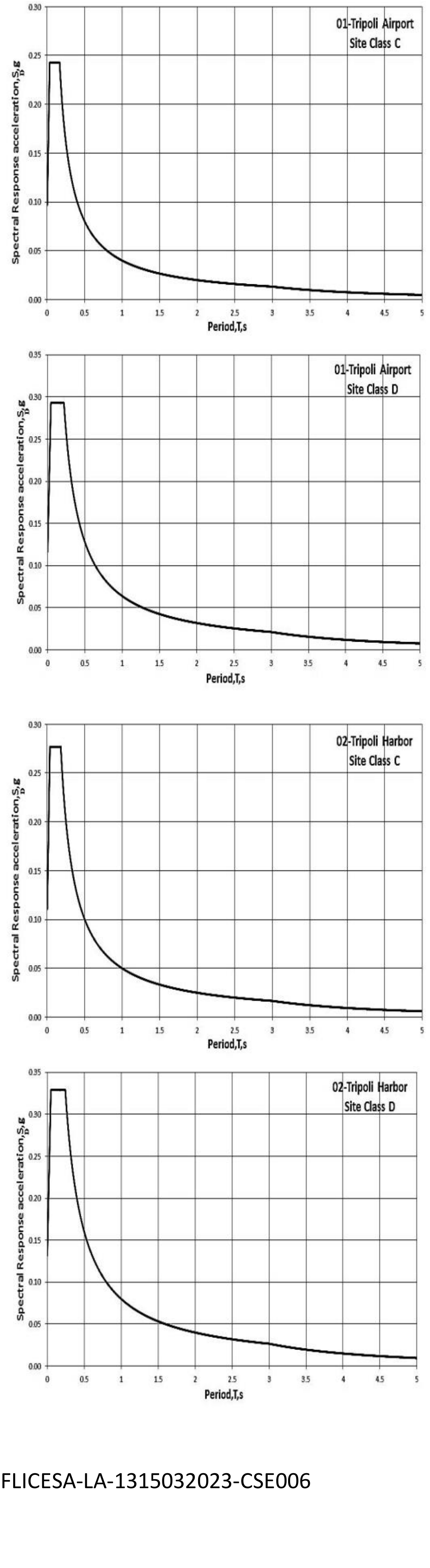



Figure 2: Standard ASCE-7 Response Spectrum Curve



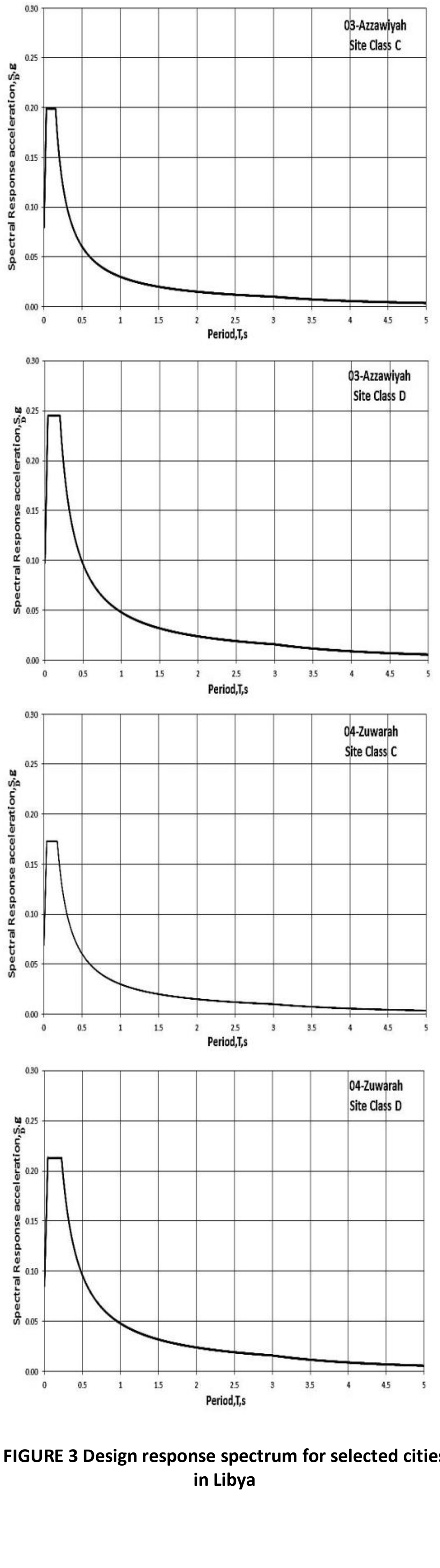




**FIGURE 3 Design response spectrum for selected cities in Libya**

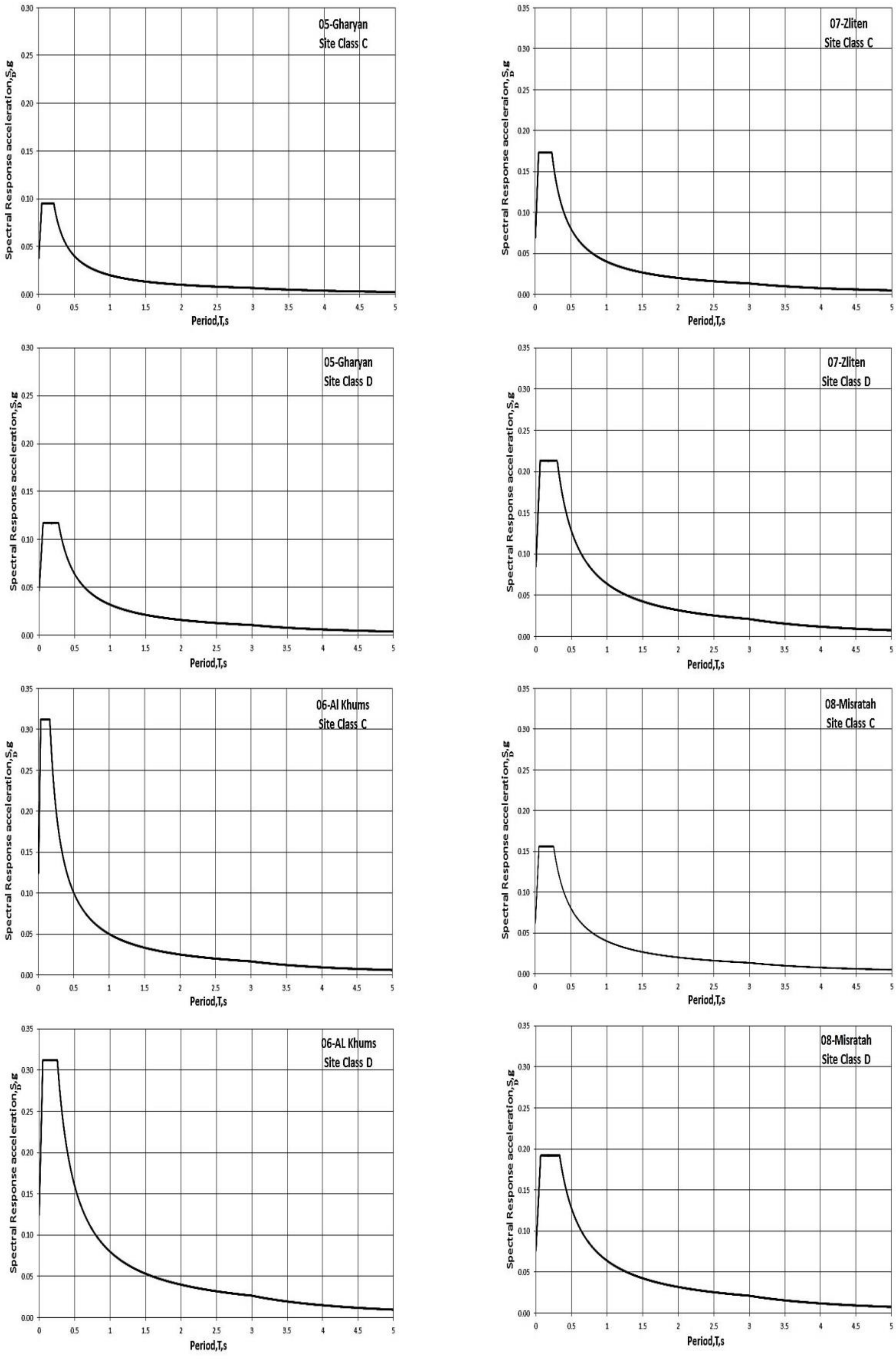



**FIGURE 3 (Continued)**

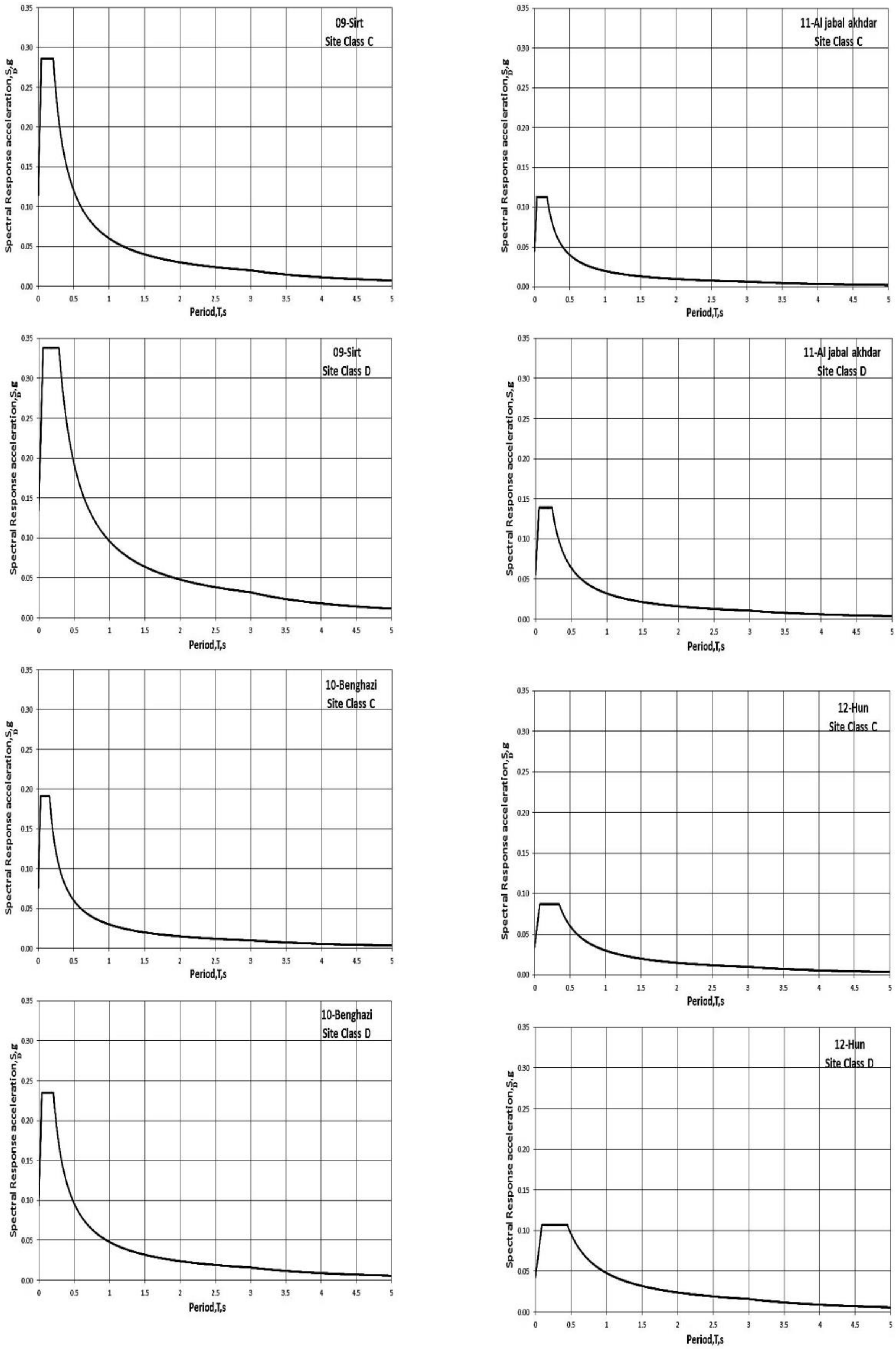
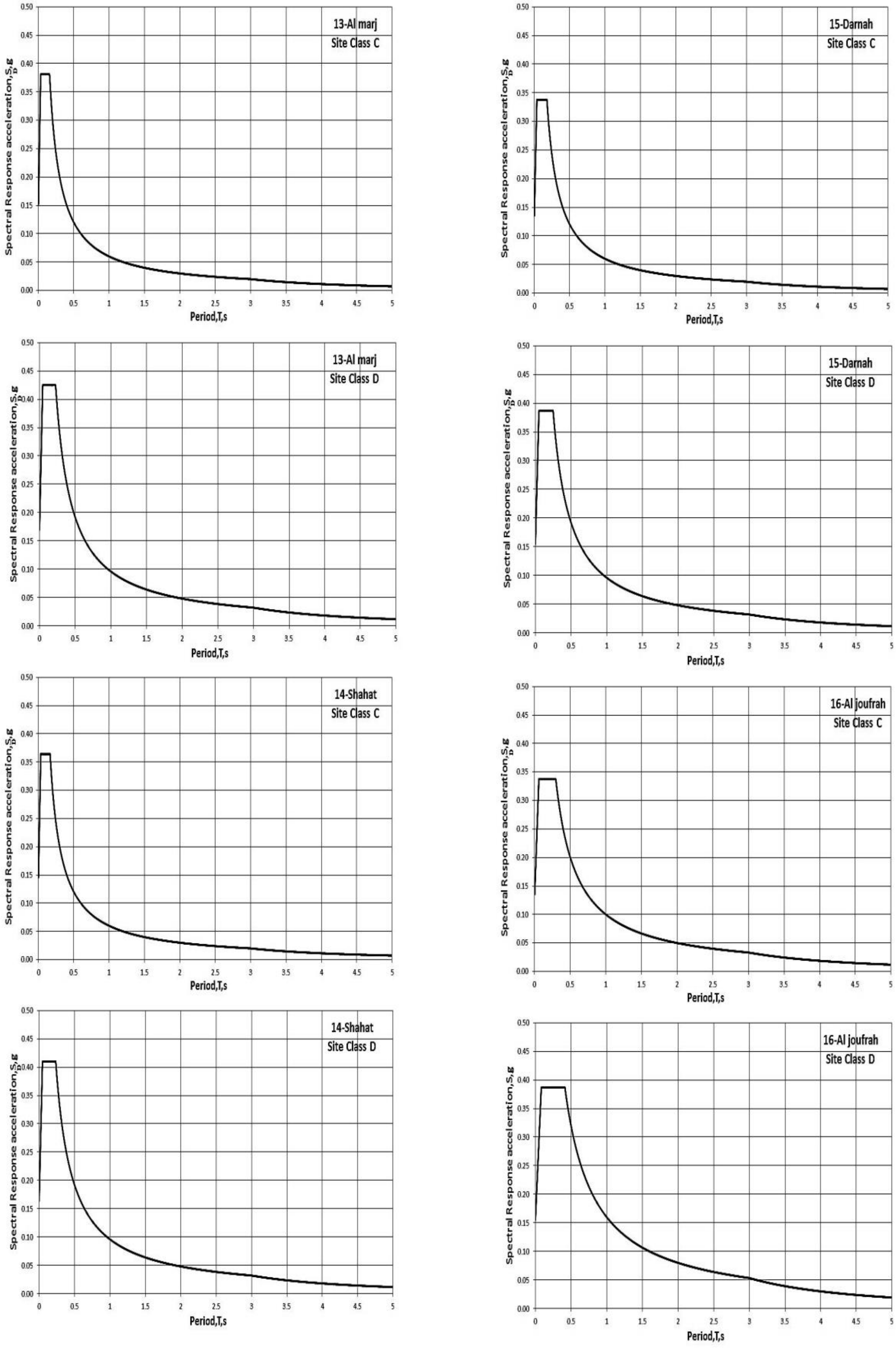



**FIGURE 3 (Continued)**

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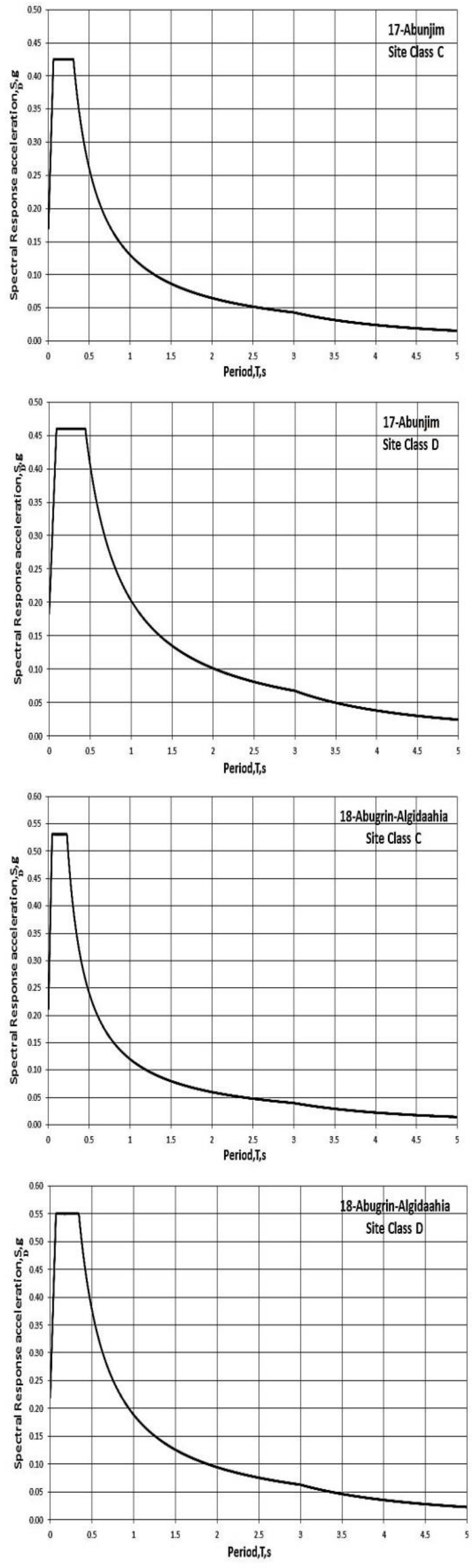


**FIGURE 3 (Continued)**

## Ⅲ DISCUSSION OF RESULTS

Figure 3 depicts the design response spectra curves for 18 Libyan cities. These curves represent the expected seismic hazard level for future earthquakes for soil site classes C and D. Using the modification factor R and the displacement amplification factor $C_d$, these curves will be modified to reflect the inelastic expected behaviour of structures. These curves represent the Design Basis Earthquake, which is defined as two-thirds of the Maximum Considered Earthquake as required by the ASCE-7 Standard. Structures are explicitly designed for DBE and safety in accordance with MCE. This is accomplished through appropriate over strength and ductility provisions. The seismic levels at MCE must be established in order to carry out this design requirement. Thereafter, the response spectra can be constructed to be used in the design process in the three main analysis procedures; (ELF, RSA and THA). The uniform hazard spectrum curves shown in Figure.3 above provide the needed information for designing seismic-resistant buildings in Libya.

## Ⅳ CONCLUSIONS

Finally, this paper presents the design response spectra curves for 18 Libyan cities with significant seismic activity. These curves were created using the seismic hazard parameters $S_s$ and $S_1$, which were determined in a previous study on Libya's seismic hazard analysis [1]. The ASCE-7-5 standard was used as the foundation for this study. These curves can now be used in conjunction with seismic design software to ensure that seismic loads are included in the design of various structures and buildings throughout the county. These response spectra curves can be modified and upgraded in accordance with the new ASCE-7-16 Standard and IBC-2019 code provisions, such that new SDs and SD1, design spectral accelerations at 0.2s and 1.0s correspond to the Mapped Risk-Targeted Maximum Considered Earthquake ($MCE_R$) which corresponds to 1% probability of collapse rather than the MCE probability of exceedance of 2% in previous code provisions based on the Seismic Hazard approach.

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