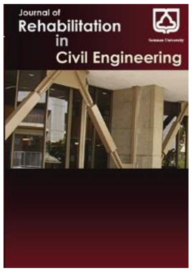

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Deterministic and Probabilistic Seismic Hazard Analysis of Petroleum Storage of Sabzevar

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ARTICLE INFO

Article history:
Received: 23 January 2021
Revised: 12 June 2021
Accepted: 26 June 2021

Keywords:
Deterministic and probabilistic;
Seismic hazard analysis;
Level of hazard;
Sabzevar;
SeisRisk III.

ABSTRACT

Failure of appropriate resource structures for petroleum products located close to residential areas has irreparable financial and fatal consequences. Thus, a seismic hazard analysis in estimating strong ground motions seems essential for constructing or improving such structures. For this purpose, firstly, by using the deterministic method and empirical equations of the largest earthquake likely to occur, the result of active faults activity was determined using attenuation equations via an appropriate logic tree, and the maximum horizontal and vertical acceleration component was calculated based on two types of soil. The first type of soil matches types I and II, and the second type matches III and IV, from standard No.2800. Then, to analyze the potential hazard, we define the seismic sources, seismic parameters, rupture parameters, and the attenuation equations with the same logic tree using SeisRisk III software, plus the maximum vertical and horizontal acceleration component, based on the two identical types of soil. Subsequently, the seismic improvement regulation of structures (*360 magazine*) for the second level hazard was calculated and finally compared with the results of the deterministic analysis. Results indicated that the acceleration component in the deterministic method presents a higher amount than the probable method. As a result, probable methods can be used instead of a deterministic method proving far more economical.

How to cite this article:
Bakhshi, H., Alavi, S., Rezaie, Z., Hassani, M. (2022). Deterministic and Probabilistic Seismic Hazard Analysis of Petroleum Storage of Sabzevar. Journal of Rehabilitation in Civil Engineering, 10(2), 17-34.
https://doi.org/10.22075/JRCE.2021.22439.1479

1. Introduction

Sabzevar city with coordinates of longitude 57 degrees 41 minutes and 0 seconds east and latitude 36 degrees 12 minutes 24 seconds north, situated in about 3,300 hectares in a gentle northern slope from north to south, is one of the largest cities in the Khorasan Razavi province. According to the 1390 census, the city's population is reported to be 319,893 people. The city provides many essential functions for the region and country, such as multiple national universities, an airport, located at the geographical and administrative center of the western cities of Khorasan Razavi, is densely populated, has a rich historical background, and plays a vital role of influence within the East of the country.

Reviewing the history of Iran's seismicity, one can understand that most seismic activities have occurred along active faults. For example, the city of Sabzevar is in the vicinity of Sabzevar active faults (74 km in length) and can create an earthquake with a magnitude of 6.92 on the Richter scale, where the relative hazard zoning according to standard No.2800 is classed as high. Due to the city's deterministic and probabilistic seismic hazard analysis, studying the role of active faults within the seismic earth sources is essential.

Seismic hazard analysis was initially proposed by Cornell et al. [1]. Increasing urbanization has led to structures for storing petroleum products among the human population and commercial zones. Strategic roles of resources lead to the importance of such structures' safety aspect, as any failure caused by a potential earthquake can cause devastating effects. In this respect, building or improving such resources is needed to calculate maximum vertical and horizontal acceleration components based on two types of soil, progressing and increasing the precision of seismic data and devices, using the two deterministic and probabilistic methods where the first type of soil matches soil types I and II. The second type matches the type of III and IV, according to standard No.2800.

Bakhshi and Rezaie have conducted a study on the preparation of accelerated plans for designing and improving structures in the city of Sabzevar using probabilistic analysis and the assistance of "SeisRisk III" software. They first identified the seismic sources, extracted the study area's seismic parameters, and optimized the results according to the reduction relationship and the appropriate logic tree. As a result, they concluded that the city's base acceleration is 0.30. Moreover, according to the analysis results, for the southern and southwestern parts of the city, the level of design risk with a return period of 475 years in 50 years of the structure's useful life has been suggested as very high [2].

Sonardi et al. conducted a study on the reassessment of seismic hazard in the city of Tasiyakmayala using a random method whose primary purpose was to reassess the seismic hazard within the city. They first analyzed the earthquake data and then examined 22 new seismic structures concerning earthquakes and concluded that seismic hazard assessment in the city via randomized maximum ground acceleration (PGA) and spectral acceleration values in the subgrade showed the likely occurrence rate as more than 2% in 50 years [3].

Chen et al. researched seismic challenges in reducing earthquake risk reflecting on earthquake occurrences in 2008. This research was conducted during the tenth anniversary of the 2008 Wenchuan earthquake, from which many lessons can be learned. In this study, researchers have concluded that the generalities of building codes and transportation methods in earthquake-prone mountainous areas should be sufficiently addressed [4].

Vicklanges et al. also presented a study on a possible comparison of seismic hazard analysis results of nuclear power plants in areas with different seismic levels. In this research, an accurate survey was prepared and distributed through the Nuclear Energy Agency, and methods were used to review this research, which helped increase the quality of studies of probabilistic analysis methods. The result of this study revealed that NEA member countries responded to the survey with different seismic levels, which were ultimately categorized into three groups: very low (Finland, Sweden), medium (France, Germany), and high (Japan). The overall purpose of this study was to summarize and combine the answers so that they can be used by other researchers [5].

Waseem et al. researched the northern part of Pakistan revolving around the definition of new regional ground motion parameters for earthquake reoccurrences of 95, 475, 975- and 2475- in strategic towns and cities. The results were regional contour maps and horizontal uniform hazards with probabilistic seismic hazard analysis methods to produce macro-seismic hazard maps [6].

Mousavi et al. showed that USGS hazard curves are variable because there is an epistemic uncertainty in its informed sub-model using a simple bootstrapping approach. The research concludes that variability is in the maximum range in low-seismicity regions. Furthermore, areas like the New Madrid seismic zone or Oklahoma with a high seismic hazard show lower variability due to more accessible information and a proper understanding of the seismicity [7].

Dipova et al. carried out a survey that leads to the promotion of seismic hazard for the Antalya area (SW Turkey) using a probabilistic approach. First, they conducted an exercise for a maximum ground acceleration and bedrock with a 10% probability hazard level exceeding in the next 50 years using a seismic hazard map. They concluded that that maximum ground acceleration magnitudes on the bedrock differ between 0.215 and 0.23 g in the center of Antalya [8].

Therefore, the analysis of seismic hazard resources of petroleum products of this city using a manually deterministic method and analyzing the seismic hazard potential using the SeisRisk III software for hazard level 2, based on the existing seismic improvement of regulation structures (360 magazine) where the maximum possible earthquake assessment capabilities and procedures are compared with the results of the deterministic method.

In this paper, a comparison is made between two types of deterministic and probabilistic methods for structures of storage facilities of petroleum products. The deterministic analysis is calculated exclusively for a particular earthquake, and probabilistic analysis considers the uncertainty related to the magnitude, location, and time of the earthquake. The comparison between the two methods is made by obtaining the amount of vertical and horizontal acceleration components. The amount of these components will determine whether each method is optimal or uneconomical. Furthermore, this comparison determines whether it is possible to use the probabilistic method to store petroleum products in Sabzevar and avoid additional and unnecessary costs.

2. Deterministic seismic hazard analysis (DSHA)

In the deterministic seismic hazard analysis of the studied site, the design parameters of the motion of the earth for a certain magnitude of an earthquake on a particular source and at a certain distance is obtained from the site using parameters such as distance, magnitude, attenuation equations, local soil conditions, among others. In this method, all parameters such as magnitude produced in the source and distance from the site were precisely selected, and then a hazard analysis was carried out.

In the hazard analysis of earthquakes by the deterministic method, regardless of the other side and complex parameters associated with the science of seismology, only the leading cause of the earthquake, i.e., seismogenic earthquake sources (faults), were studied and regardless of the probability of occurrence, maximum motion parameters of the earth with the employment of the reduction model in the desired area was calculated and estimated. In other words, using this method, the view of interest is that if the most critical seismic mode is designed, the intended safety for the area case study against the hazard of an earthquake will be obtained.

In contrast, if a critical design mode is not applied, information such as the probability of a controller earthquake occurrence, position of occurrence, position of vibration levels expected during a specific time, or various hazards (such as the useful life of a structure or special devices) and, finally, effects of uncertainties in different levels will not be obtained hence the analysis will lead be very conservative results.

3. Analysis of deterministic seismic hazard of petroleum product resources

An effective deterministic analysis method for evaluating structures that collapse, such as atomic power plants, large dams, and storage facilities for petroleum products that have disastrous effects, consists of a clear evaluation framework for evaluating the most critical vibrations of the earth.

In seismic regulations such as the International Commission of large dams (ICOLD) [9] and standard No.2800 (ICSRDB) [10], according to the level of importance of the structural seismic hazard analysis for the design level, MCL is used for the deterministic method to estimate the earth motion parameters used.

The maximum earthquake occurrence level (MCL) for parameters of the largest earthquake due to the nearest fault, the largest historical earthquake, or the largest earthquake that can tectonically occur in the area may be defined.

The deterministic seismic hazard analysis method consists of four major steps:

3.1. Detecting seismic sources

The role of active faults in the earth's seismic categorization and the realization that faults are the most critical linear seismogenic source towards the extraction of the active fault zone profile radius of 200 kilometers from the city of Sabzevar, such as the length of the fault, and their closest distance to the studied site, are investigated. (**Table 9**) in the range of study, there are 26 active faults visible in **Fig. 1**.

3.2. The determination of controller seismic

In both methods, probabilistic and deterministic seismic hazard analysis, it is necessary to estimate the probable earthquake in the area, especially to frequently estimate the largest earthquake caused by a fault in the area. Also, to calculate the maximum magnitude of the event, the largest occurred earthquake will be extracted from the database. Due to the fault rupture length, and using the experimental relations existing between rupture length and magnitude, the maximum magnitude of the occurrence is estimated. The ones that are bigger than the other are selected as M_{max} or controller earthquake. Studies have shown that earthquakes are directly relative to a magnitude of fault rupture parameters such as the length of rupture or displacement faults. The result of studies led to equations between fault rupture length and the earthquake magnitude caused by it, and the equation depends on the recognition of the tectonic and seismic tectonic behaviors on the project scope. This equation is generally defined as Equation 1 [11]:

$$\text{Log } L_R = a + b\,M \qquad L_R=\%30\sim\%100L \tag{1}$$

Where L_R is fault rupture length, L is fault length, and a and b are constants.

Since the entire fault length does not interfere with the earthquake, only fault rapture length enters the calculation. Fault rupture can be variable and covers a broad spectrum of length. This length is often between 30 to 100 percent of the entire length of the fault. For cases where the real length is 300 km, the rapture length equals 37% of the real length, and for a fault of 100 km, this equals 50%, and finally, for faults smaller than 100 km, this is 100% of the real length.

Using the following empirical equations calculates controller earthquake and optimized results using the logic tree and the weight factor (**Fig. 2**). The results are shown in **Table 9**.

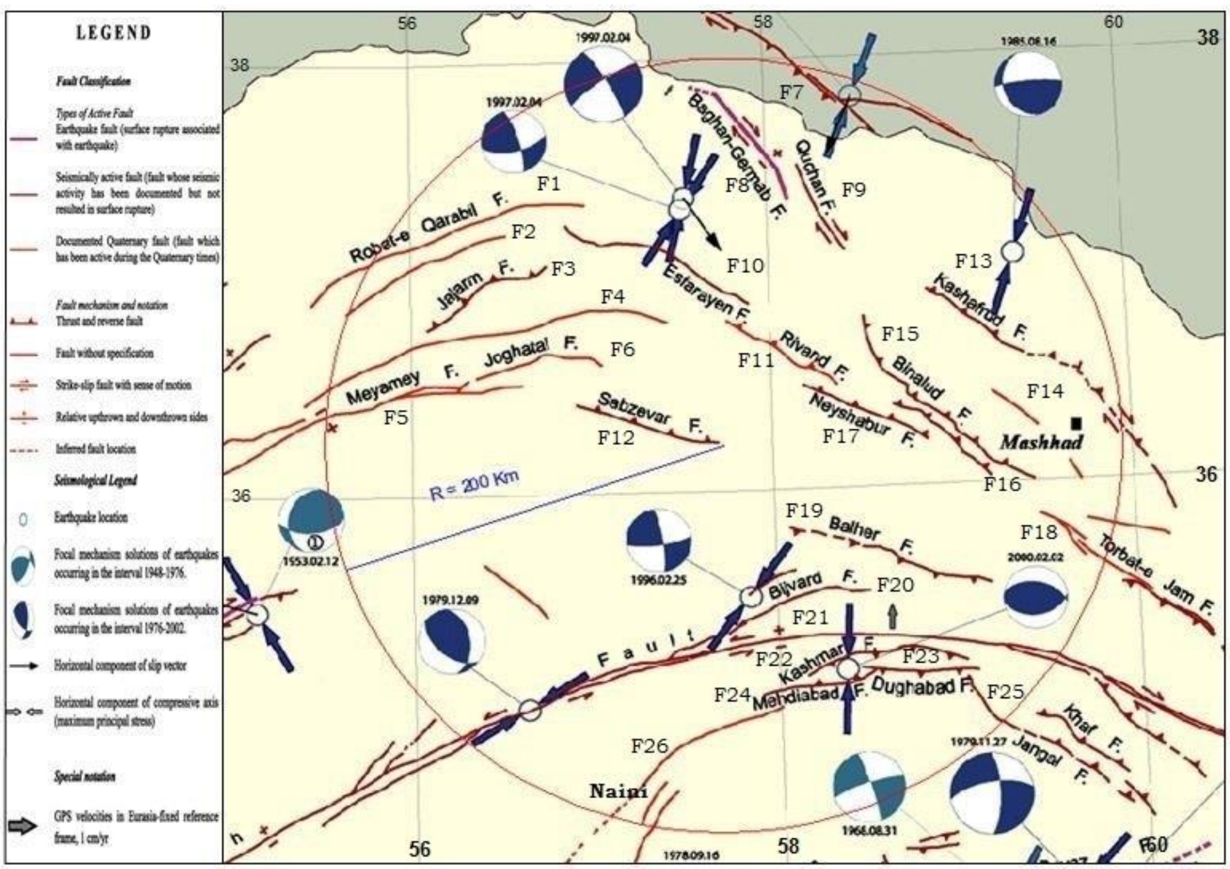

Fig. 1. Active faults within 200 km from the city of Sabzevar [12, 13].

Norouzi Equations [14]	$M_S=1.259+1.244 \text{ Log } L$; L(m)	(2)
Ambraseys-Melville equation [15]	$M_S=5.4+\text{Log}L$; L(Km)	(3)

Wells-Cooper Smith equations (6):

Slip fault	$M_S=5.16+1.12 \text{ Log } L$; L(Km)	(4)
Reverse fault	$M_S=5+1.22 \text{ Log } L$; L(Km)	(5)
Normal fault	$M_S=4.86+1.32 \text{ Log } L$; L(Km)	(6)
All faults	$M_S=5.08+1.16 \text{ Log } L$; L(Km)	(7)

Solmaz equations (8):

Slip fault	$M_S=1.404+1.16 \text{ Log } L$; L(m)	(8)
Reverse fault	$M_S=2.021+1.142 \text{ Log } L$; L(m)	(9)
Normal fault	$M_S=0.809+1.341 \text{ Log } L$; L(m)	(10)

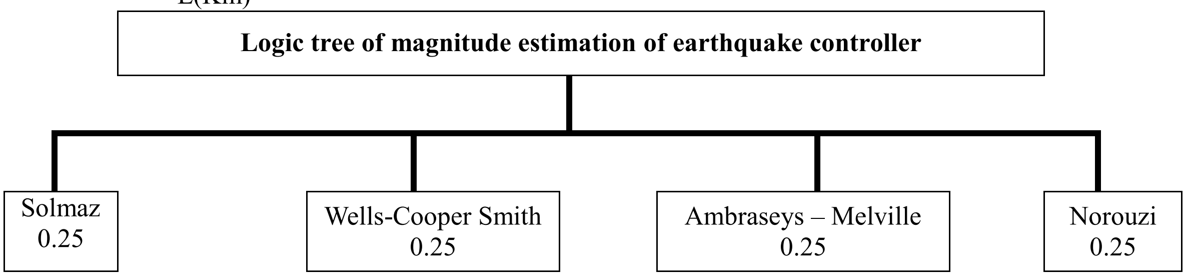

Fig. 2. Logic tree of magnitude estimation of controller earthquake.

3.3. Select reduction equations

The relationship between components of ground motion (velocity, spectral response, displacement, acceleration, magnitude, and distance) is stated and defined with experimental equations called attenuation equations. Many researchers use these equations for many variable regions or worldwide.

In select attenuation equations, considerations such as distance seismic source of location, magnitude, focal depth, type of earth of the desired area, the dominant mechanism of seismic sources, and the standard error should be considered. The method of calculating maximum horizontal and vertical acceleration in all attenuation equations is by dividing the soil. Some of the reduction equations used:

Ramazi-Schenk reduction equation 1994 [16]:

$$a = a_1 (a_2 + d + H)^{a5} \exp(a_6 M_S) \; ; H = |d - a_3|^{a_4} \; ; a = cm / s^2 \quad (11)$$

Suggested factors for equation (11) are shown in **Table 1**.

Table 1. Suggested coefficients in Ramazi-Schenk relationship 1994 [16].

acceleration component		a_1	a_2	a_3	a_4	a_5	a_6
a_h	Soil	4000	20	16	0.63	-2.02	0.8
	Rock	4000	20	16	0.63	-2.11	0.79
a_v	Soil	4000	20	16	0.48	-1.75	0.53
	Rock	4000	20	16	0.48	-1.75	0.53

Campbell-Bozorgnya reduction equation 2000 [17]:

$$\ln Y = c_1 + c_2 M_W + c_3 (8.5 - M_W)^2 + c_4 \ln (\{R_S^2 + [(c_5 + c_6 \{S_{PS} + S_{SR}\} + c_7 S_{HR}) \exp (c_8 M_W + c_9 \{8.5 - M_W\}^2)]^2 \}^{1/2}) + c_{10} F_{SS} + c_{11} F_{RV} + c_{12} F_{TH} + c_{13} S_{HS} + c_{14} S_{PS} + c_{15} S_{SR} + c_{16} S_{HR} \; ; Y = g \quad (12)$$

Calculated factors of equation (12) are shown in **Tables 2 to 4**.

Table 2. Suggested constant coefficients for the Bozorgnya reduction equations 2000 [17].

Uncorrected Horizontal Component of Acceleration	C1=-2.896	C2=0.812	C3=0	C4=-1.318	C5=0.187	C6=-0.029
	C7=-0.064	C8=0.616	C9=0	C10=0	C11=0.179	C12=0.307
	C13=0	C14=-0.062	C15=-0.195	C17=-0.320	σ =0.509	
Uncorrected Vertical Component of Acceleration	C1=-2.807	C2=0.756	C3=0	C4=-1.391	C5=0.191	C6=0.044
	C7=-0.014	C8=0.544	C9=0	C10=0	C11=0.091	C12=0.223
	C13=0	C14=-0.096	C15=-0.212	C16=-0.199	σ =0.548	

Table 3. Division of soil types in Bozorgnya reduction equation [17].

Holocene Soil (HS)	**V_{S30}=290m/s**	**S_{HS}=1**	**S_{PS}=0**	**S_{SR}=0**	**S_{HR}=0**
Pleistocene Soil (PS)	V_{S30}=370m/s	S_{HS} =0	S_{PS} =0	S_{SR} =1	S_{HR}=0
Soft Rock (SR)	V_{S30}=420m/s	S_{HS} =0	S_{PS} =0	S_{SR} =1	S_{HR}=0
Hard Rock (HR)	V_{S30}=800m/s	S_{HS} =0	S_{PS} =0	S_{SR} =0	S_{HR}=1

Table 4. Division faulting mechanism [17].

Strike Slip	**F_{TH}=0**	**F_{SS}=1**	**F_{RV}=0**
Reverse	F_{TH}=0	F_{SS}=0	**F_{RV}=1**
Thrust	F_{TH}=1	F_{SS}=0	**F_{RV}=0**

Khademi reduction equation 2002 [18]:

$$Y = C_1 \exp (C_2 M_W) ((R + C_3 \exp (C_4 M_W))^{C_5}) + C_6 S \; ; Y = g \quad (13)$$

Proposed factors for equation (13) are presented in **Table 5**.

Table 5. Suggested coefficients for the Khademi reduction equations in 2002 [18]

Acceleration Component		**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**S**
Horizontal Component	Soil	0.040311	0.417342	0.001	0.65	-0.035852	-0.035852	1
	Rock	0.040311	0.417342	0.001	0.65	-0.035852	-0.035852	0
Horizontal Component	Soil	0.0015	0.8548	0.001	0.4	-0.4	-0.463	1
	Rock	0.0015	0.8548	0.001	0.4	-0.4	-0.463	0

Nourozi attenuation equation 2005 [19]:

$$\ln (A) = c_1 + c_2 (M_W - 6) + C_3 \ln (\sqrt{EPD^2 + h^2}) + c_4 S \; ; A = cm / s^2 \quad (14)$$

Table 6. Suggested coefficients for the Norouzi reduction equations 2005 [19].

Acceleration component		C_1	C_2	C_3	C_4	h	σ	S
Horizontal Component	Gravel & sand	7.969	1.220	-1.131	0.212	10	0.825	1
	Rock & Alluvial	7.969	1.220	-1.131	0.212	10	0.825	0
Horizontal Component	Gravel & sand	7.262	1.214	-1.094	0.103	10	0.773	1
	Rock &Alluvial	7.262	1.214	-1.094	0.103	10	0.773	0

Mahdavian reduction equation 2006 [20]:

$$\text{Log}(y) = a + b\,M_S + c\,\log(R) + d\,R\ ;\ y = cm/s^2 \tag{15}$$

Suggested factors for equation (15) are shown in **Table 7**.

Table 7. Suggested coefficients for the Mahdavian reduction equations 2006 [20].

	Floor	Earthquake parameters	a	b	c	d	σ
Alborz and Central Iran	of stone	PGAH	2.058	0.243	-1.02	-0.000875	0.219
		PGAV	1.864	0.232	-1.049	-0.000372	0.253
	of soil	PGAH	1.912	0.201	-0.79	-0.00253	0.204
		PGAV	1.76	0.232	-1.013	-0.000551	0.229

Ghodrati reduction equation 2007 [21]:

$$\text{Ln}\ y = C_1 + C_2 M_S + C_3\,\text{Ln}\,(R + C_4 \exp[M_S]\,) + C_5 R\ ;\ y = cm/s^2 \tag{16}$$

Proposed factors for equation (16) are presented in **Table 8**.

Table 8. Suggested constant coefficients for the Ghodrati reduction equation2007 [22].

	Floor	Earthquake Parameters	C_1	C_2	C_3	C_4	C_5	σ
Alborz and Central Iran	of stone	PGAH	4.15	0.623	-0.96	-	-	0.478
		PGAV	3.46	0.635	-0.996	-	-	0.49
	of soil	PGAH	3.65	0.678	-0.95	-	-	0.496
		PGAV	3.03	0.732	-1.03	-	-	0.53

3.4. Strong ground motion calculation

After determining the attenuation equations of the maximum ground motion, each of the studied fault areas is calculated and results optimized using the logic tree (**Fig. 3**).

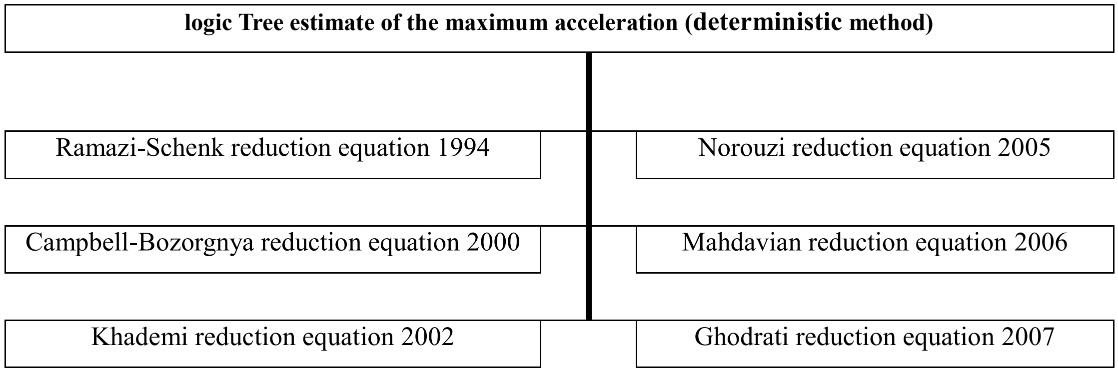

Fig. 3. Logic tree estimation of the maximum acceleration (deterministic method).

Table 9. Estimation of the magnitude and maximum acceleration based on the deterministic method.

Row	The name of the fault	Mechanism	Length fault	Length failure	Nearest	The magnitude estimated by an empirical equation					The acceleration components			
			Km	Km	Km	Norouzi	Amberseeze – Melville	Wells	Solmaz	Ms=Mw	H-II	V-II	H-III	V-III
F1	North Gharbil Robat	Normal	111.80	41.37	129.70	7.00	7.02	6.74	7.67	7.10	0.0676	0.0352	0.0650	0.0369
F2	South Gharbil Robat	Normal	91.78	45.89	141.56	7.06	7.06	6.79	7.72	7.16	0.0650	0.0340	0.0622	0.0357
F4	Jajarm South	Normal	191.60	70.89	57.32	7.29	7.25	7.01	7.19	7.19	0.1530	0.0819	0.1590	0.0868
F5	Miami	Normal	101.66	50.83	93.97	7.11	7.11	6.84	7.48	7.13	0.0922	0.0488	0.0920	0.0514
F6	Goghatai	Normal	66.83	33.41	60.69	6.89	6.92	6.63	7.22	6.92	0.1170	0.0613	0.1187	0.0645
F10	Esfaraien	Normal	100.05	50.03	67.89	7.10	7.10	6.83	7.29	7.08	0.1198	0.0635	0.1222	0.0670
F18	Torbat Jam	Normal	41.82	20.91	171.28	6.63	6.72	6.39	7.83	6.89	0.0460	0.0228	0.0414	0.0237
F20	Bijord	Normal	73.25	36.62	97.26	6.94	6.96	6.67	7.50	7.02	0.0818	0.0427	0.0805	0.0448
F26	Naieni	Normal	44.88	22.44	148.00	6.67	6.75	6.43	7.74	6.90	0.0520	0.0261	0.0479	0.0272
F14	Mashhad	Normal	63.87	31.93	146.86	6.86	6.90	6.60	7.74	7.03	0.0574	0.0294	0.0538	0.0307
F7	Turkmanistan	Reverse	51.02	25.51	173.55	6.74	6.81	6.72	8.00	7.07	0.0513	0.0262	0.0472	0.0273
F11	Rivand	Reverse	63.87	31.93	53.25	6.86	6.90	6.84	7.42	7.01	0.1422	0.0752	0.1464	0.0794
F12	Sabzevar	Reverse	74.97	37.49	15.84	6.95	6.97	6.92	6.82	6.92	0.4192	0.2193	0.4421	0.02321
F13	Kashaf Roud	Reverse	118.50	43.85	134.04	7.03	7.04	7.00	7.88	7.24	0.0725	0.0385	0.0705	0.0404
F22	Kashmar	Reverse	81.37	40.68	135.02	6.99	7.01	6.96	7.88	7.21	0.0706	0.0373	0.0684	0.0392
F23	Dough Abad	Reverse	63.15	31.58	144.52	6.86	6.90	6.83	7.91	7.12	0.0624	0.0325	0.0594	0.0340
F24	Mehdiabad	Reverse	56.49	28.24	139.45	6.80	6.85	6.77	7.90	7.08	0.0622	0.0322	0.0591	0.0337
F25	Jangal	Reverse	38.56	19.28	180.74	6.59	6.69	6.57	8.02	6.97	0.0463	0.0231	0.0417	0.0241
F15	Northern Binalood	Reverse	106.81	39.52	95.27	6.98	7.00	6.95	7.71	7.16	0.0927	0.0492	0.0926	0.0518
F16	Southern Binalood	Reverse	64.15	32.08	98.05	6.86	6.91	6.84	7.72	7.08	0.0853	0.0448	0.0843	0.0471
F17	Neishaboor	Reverse	68.51	34.26	56.15	6.90	6.93	6.87	7.44	7.04	0.1387	0.0735	0.1428	0.0776
F19	Balhar	Reverse	130.25	48.19	66.41	7.08	7.08	7.05	7.53	7.19	0.1331	0.0712	0.1371	0.0753
F8	Baghan-Garmab	Reverse	77.04	38.52	124.70	6.96	6.99	6.70	7.33	6.99	0.0643	0.0331	0.0613	0.0346
F9	Quchan	Seismic extension	48.63	24.31	115.94	6.71	6.79	6.47	7.28	6.81	0.0602	0.0303	0.0567	0.0316
F21	Darouneh	Seismic extension	296.48	109.70	112.90	7.53	7.44	7.23	7.27	7.37	0.0932	0.0505	0.0935	0.0533

4. Results and Discussions

In this article, the hazard analysis results of potential seismic Sabzevar townships have been used to obtain the maximum horizontal and vertical acceleration point maps based on the existing seismic improvement regulation of structures (1381) [23]. For hazard level 2, this is 2% in the next 50-year probability of the event with a return period of 2475 years. Therefore, an earthquake hazard level 2 In Iran, according to standard No.2800, is called the maximum probable earthquake (MPE). Furthermore, analysis results can be compared with the maximum possible earthquake results derived from the deterministic method for fuel source locations with coordinates latitude 36.21634 and longitude 57.69581.

The outputs of two alternative constructions, one with hard soil and the other with soft soil, have been measured, and an identical acceleration graph has been produced and presented through 66 grids. (**Fig. 4** to **Fig. 7**).

Sabzevar is also subject to earthquakes due to its closeness to Sabzevar's fault, known as the "nearby basin." These earthquakes are more significant and have more devastating consequences than earthquakes induced by other sources with the same power due to the pulsed nature of earthquakes and the force applied to structures within the time frame. Therefore, essential considerations must be considered in the design and improvement of structures, and the effect of the vertical component can not be ignored; hence the maps were divided into two categories: vertical and horizontal components.

It should be noted that according to Iran's standard No. 2800, the vertical acceleration component values are equivalent to 2.3 times the horizontal component values in places where seismic calculations are not performed, and this article calculates a decent approximation of this ratio for the city of Sabzevar. Furthermore, because Sabzevar city is situated in an area with a relatively higher risk level, the plan's basis acceleration equals 0.3 acceleration of the earth's gravity.

The city of Sabzevar is located in a region with a high relative risk level, according to the quadruple classification table of seismic zones in Iran's standard No. 2800.

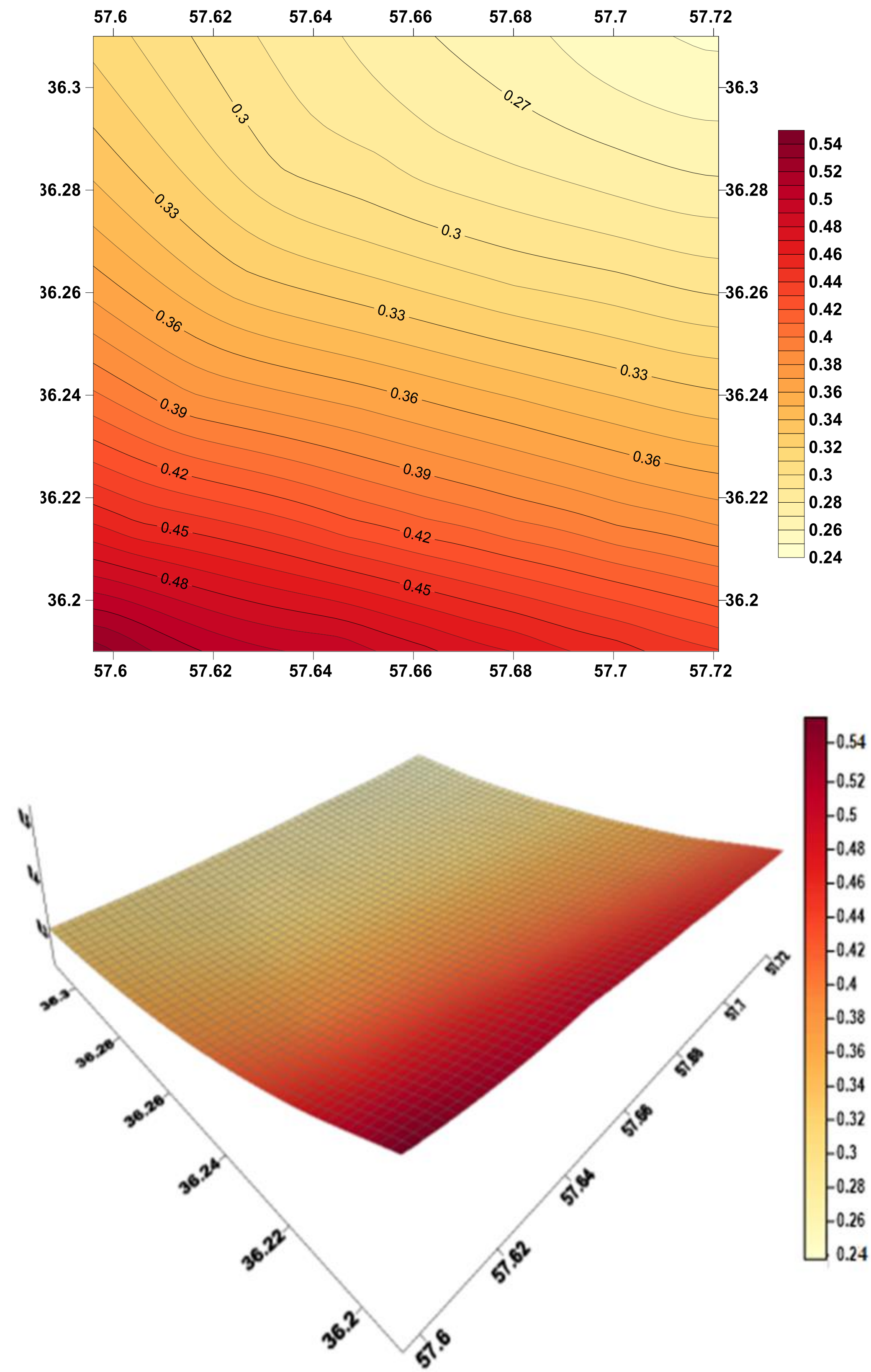

Fig. 4. Horizontal acceleration component map area, soil type I and II with a probability of 2%.

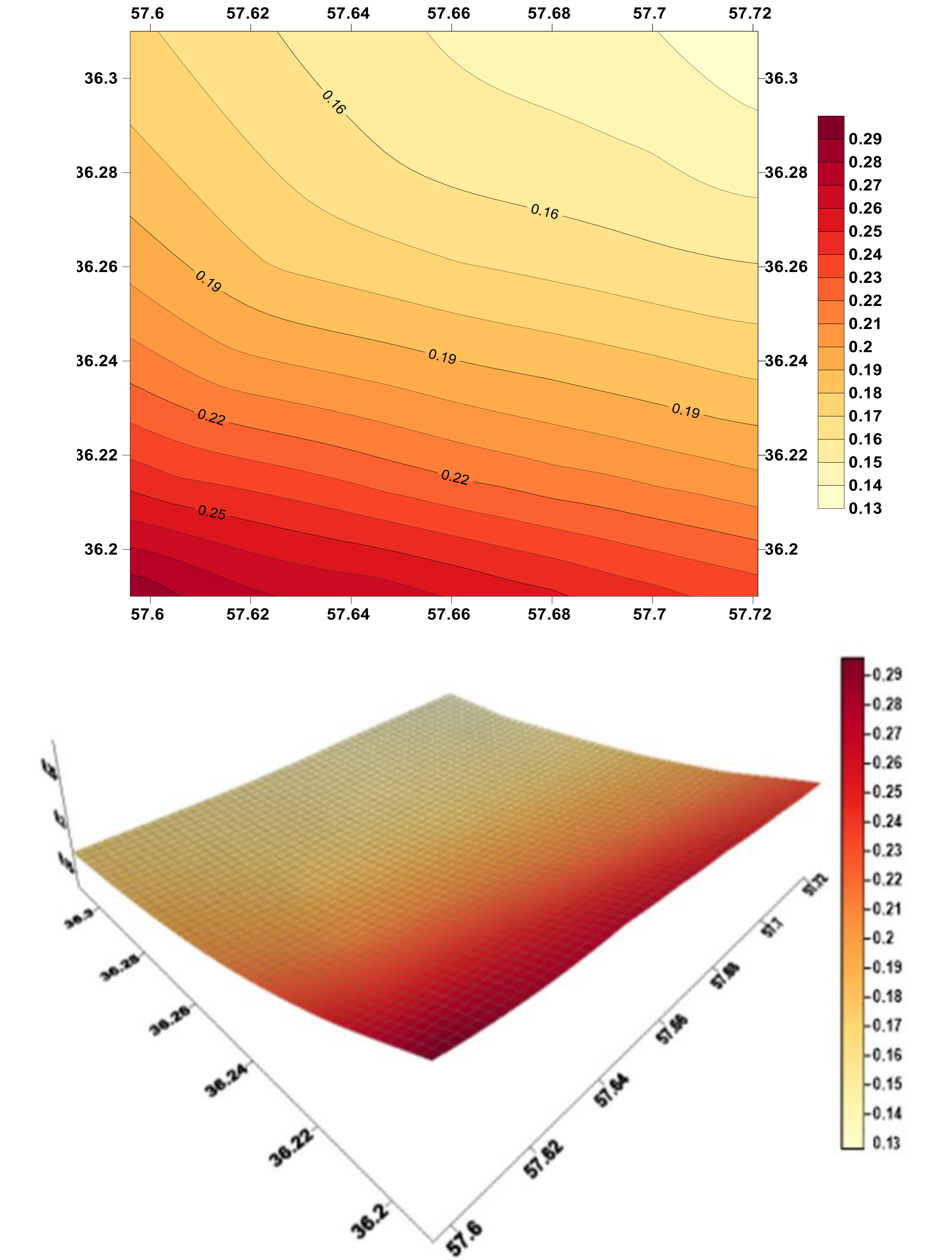

Fig. 5. Map of the vertical component of the acceleration area, soil type I and II with a probability of 2%.

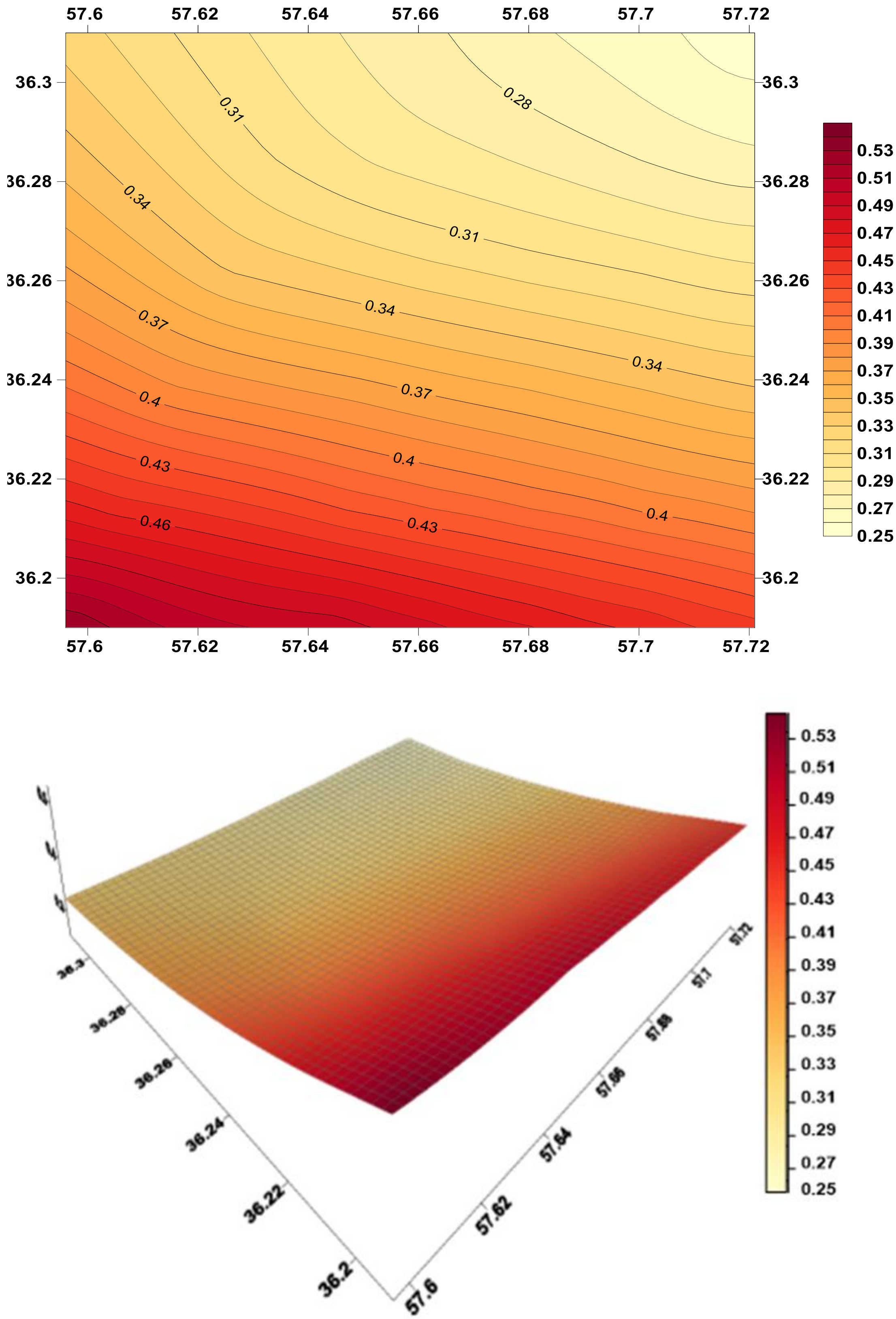

Fig. 6. Horizontal acceleration component map area, soil type III and IV with a probability of 2%.

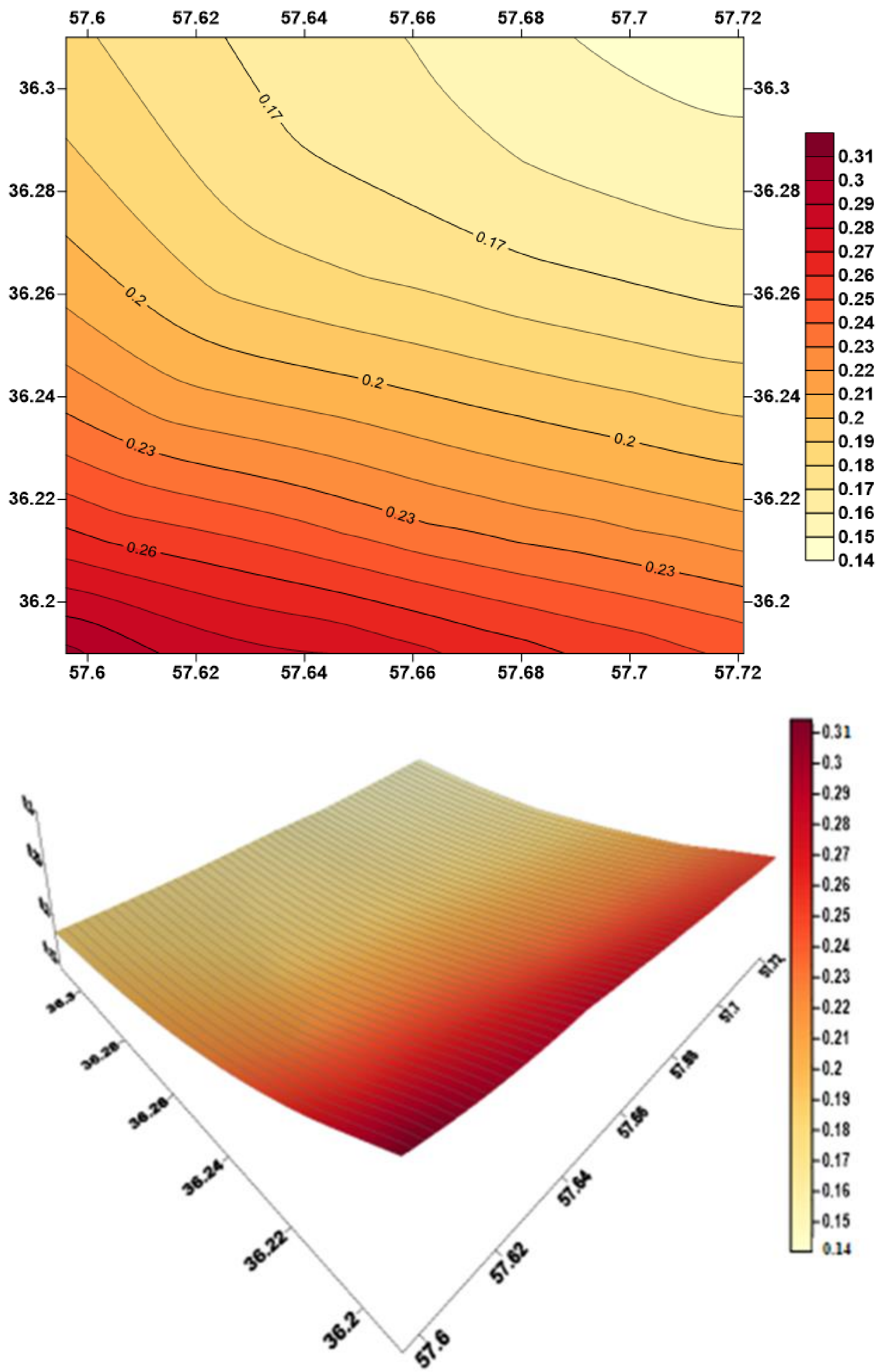

Fig. 7. Vertical acceleration components map area, soil type III and IV with a probability of 2%.

5. Conclusion

The deterministic seismic hazard analysis results for oil storage resources in Sabzevar with latitude and longitude coordinates of 57.695 and 26.216 indicate that in type 1 soil, the most significant horizontal and vertical acceleration is related to the Sabzevar fault with a ground acceleration of 0.4192 and 0.2193, respectively. In the second type of soil, these values are estimated to be 0.4421 and 0.2321, respectively. These results are compared with the results extracted from the horizontal and vertical maximum component maps for hazard level 2 with a probability occurrence of 2%, called the maximum probable earthquake in standard No. 2800 shown in **Table 10**.

The acceleration component in the deterministic method shows a higher amount than the probable method. However, in the probable method, the uncertainty that arises from the magnitude, the place, and the rate of occurrence of these earthquakes is stipulated; therefore, it could be used in place of a deterministic method and is far more economical.

It should be noted that necessary actions to improve and modernize these resources should be based on the results shown in **Table 10.**

Table 10. Comparison of results of deterministic and probabilistic analysis of petroleum product resources.

Acceleration components								Type analysis	Coordinate	
Probabilistic				Deterministic						
IV, III		II, I		IV, III		II, I		Type of soil	width	length
Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Direction		
								Level of hazard		
0.220	0.398	0.209	0.392	0.2321	0.4421	0.2193	0.4192	%2	36.21634	57.69581

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Appendix 1 (Notation List)

Seismic parameters used for analysis and derivation of coefficients in the acceleration attenuation relationships are as follows:

$L_{R.}$	Fault Rupture Length in (Km).
L	Fault Length in (Km).
d	Focal Depth (Km).
EPD	Epicentral Distance (EPD) is the distance between the accelerometer and the seismic source in km.
H	Joyner-Boore Distance, which is commonly *EPD* plus a constant term called Joyner-Boore distance.
R	Generic Distance from the Source.
$M_{S.}$	Surface Wave Magnitude of the Occurrence Earthquake.
M_{max}	Maximum Magnitude of the Occurrence Earthquake.
$M_{W.}$	Recalculated Moment Magnitudes.
Y	Strong Ground Motion Parameter in (cm/s^2).
a_i	Horizontal, or Vertical Acceleration Components in (cm/s^2).
A	Peak Horizontal, or Peak Vertical Accelerations in (cm/s^2).
V_{S30}	Time-Averaged Shear-Wave Velocity in the Top 30 m of the site in (m/sec).

S_{HS}, S_{PS}, S_{SR}, $S_{HR.}$	*S* an indicator variable representing regional site effects and conditions, and HS, PS, SR, and HR are summarized Holocene Soil, Pleistocene Soil, Soft Rock, and Hard Rock.
F_{TH}, $F_{SS,}$ and $F_{RV.}$	*F* is faulting mechanism; a function expressing ground motion at the source, FTH, FSS, and FRV is an indicator variable representing Thrust Horizontal, Strike-Slip, and Reverse Vertical faulting, respectively.
PGAH	Peak Ground Horizontal Accelerations in (cm/s^2).
PGAV	Peak Ground Vertical Accelerations in (cm/s^2).
a and b	Seismicity Coefficients.
C_i and σ	are constants coefficients and are determined by regression analysis and may be positive or negative.