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MODELS OF SEISMIC MICROZONING FOR APSHERON PENINSULA AND BAKU METROPOLIS, AZERBAIJAN

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SUMMARY

The basic point in seismic microzoning study is to provide strong seismic motions over the areas and vulnerability to destructive earthquakes. Seismic microzoning maps allow conducting estimations of the seismic hazard, evaluating probable damages to infrastructures due to earthquake disasters. For carrying out these aspects successfully, it is fundamentally necessary to determine careful investigation of a researching area in terms of not only seismicity, but also surface and base geology, geomorphology, topography and soil conditions. In this study, Apsheron Peninsula, including Baku City-the capital of Azerbaijan Republic was researched by seismicity, target earthquakes, attenuation, soil and rock properties, geological crossection, the boring data of measured shear-wave velocity, ground modeling, amplifications and base rock and surface ground motions. The process of research was done using visualization techniques applying SHAKE program (Japanese version) and MapInfo Professional 4.5 (USA). Defining an amplification factor of the each geological unit through shear wave velocity was important and necessary in order to apply attenuation formula for calculating Peak Ground Acceleration (PGA) at base rock, because calculating PGA at surface seismic motion was proceeded by multiplication PGA at the base rock with amplification parameter of each surface layers all the way through 3800 meters. The result of data processing, modeling, mapping, interpreting made it possible to identify certain regularities in the attenuation of the earthquake intensities, to classify soil conditions, to determine peak ground acceleration at base rock and ground surface caused by target earthquakes. In this approach, Quaternary type of deposits were examined in detail, because for the areas with living objects, villages, small towns Quaternary outcrops represent the fact of risk with increasing PGA value at the surface. In this paper, there was an attempt to apply the relationship between PGA values with MSK scale of seismic intensity. Finally, seismic microzoning numerical models of PGA value was drawn which gives the possibility for estimating a level of a seismic motion, the visual seismic intensity picture of the researched area for countermeasures plans, for future assessment and for mitigating the level of future disasters.

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INTRODUCTION

Apsheron Peninsula with the part of the Apsheron water area (Azerbaijan sector of Caspian Sea), lies in the southeastern downwarp of the Greater Caucasus. Most epicenters of destructive earthquakes in this zone can be placed in a group with magnitude range 5.5-6.5. The intensity of shaking on the Apsheron Peninsula during earthquakes with foci in Baku comes to VII by MSK scale. Meanwhile, for Mashtaga area, according to the records of the 1842 Mashtaga earthquake (30 km to the northern-eastern from Baku with magnitude 5), the intensity can reach VIII. Based on the past historical data, it is recommendable to consider Apsheron Peninsula as a seismically active zone. From geological viewpoint, most of Apsheron Peninsula's area is embraced by Quaternary outcrop which represents high risk concerning house building, construction, due to the soil characteristics.

As for January the 1st, 2001, the population of Apsheron Peninsula including Baku city has reached 2,181,600, whereas the total area is 5,400 km² and population density comes up to 404 people per 1 km². Meanwhile, for Baku city, the density reaches the point of 10000 people per 1 km².

In addition to that, seismic future risk is increasing because of a number of reasons, such as population increase, enlargement of a city area, existence of many older buildings, the raise of underground waters` level and the level of Caspian Sea, land watering and land subsidence. All those facts indicate that the level of expected damages and losses will be very high once an earthquake disaster occurs.

Bearing in mind high seismic activity, past historical earthquakes, vulnerability of the area, future risk probability, it is recommendable to provide microzoning study for Apsheron Peninsula with an aim of mitigating the level of future earthquake disaster.

The processes of this study are shown in Figure 1.

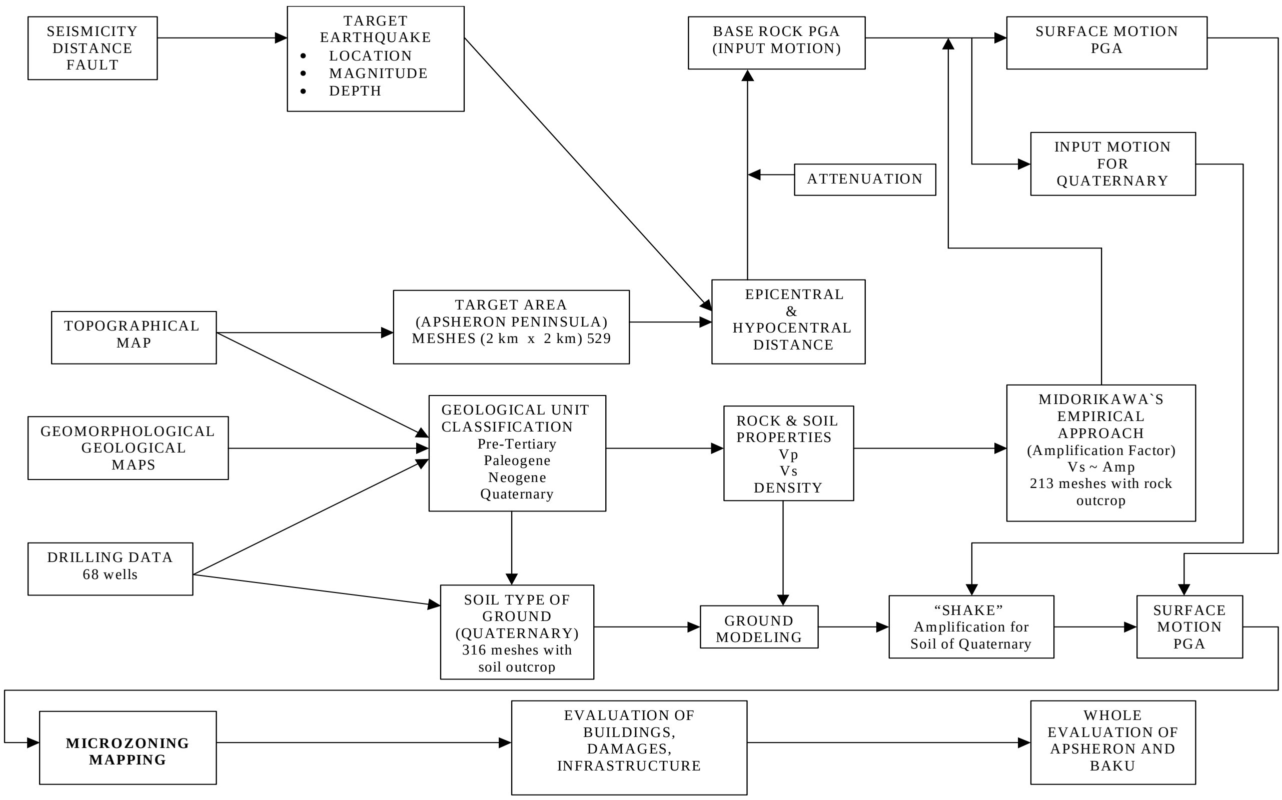

Figure1. Flowchart for Microzoning Study of Apsheron Peninsula, including Baku City.

TARGET EARTHQUAKE SELECTION

The basic procedure for estimating the ground motions starts from choosing target earthquakes that was a fundamental aspect. According to Earthquake Catalogue of Apsheron Peninsula and adjacent territory of Caspian Sea with onshore area (Figure 2), there occurred many earthquakes with different magnitudes, locations, depths and influences [1, 2]. New temporary scheme of general seismic microzoning for Apsheron Peninsula shows that two seismic zones exist over Apsheron Peninsula. One zone is located in the northern part of peninsula with 100-year return period and with magnitude 8, and another zone surrounds Apsheron from south with return period of 1000 years and with the same magnitude [3].

In addition to that, most of the earthquakes occurred within the two seismically active zones, surrounding Apsheron Peninsula. First zone, is a zone from north, that is a continuation of Main Caucasus Fault System running through northern coastal side of Apsheron Peninsula and Caspian Sea territory to the west of Turkmenistan. The destructive Mashtaga earthquake of 1842 (30 km to the northern-eastern from Baku) occurred in this zone [4]. Besides, some moderate earthquakes with magnitude M=6-6.5 (1983, 1989) occurred within this zone. Second one is a zone from south, which is considered to be an eastern continuation of Vandam zone bounding Apsheron Peninsula from south. The recent Caspian earthquake of November 25, 2000 (M=6.5) occurred in this zone (35 km to the south from Baku), which caused 35 victims, 1,292 building damage, 3 collapsed buildings and so on.

Out of those events, two types of earthquakes could be selected. The last Caspian earthquake with foreshock (M=5.8, depth 50.4 km) and with mainshock (M=6.5, depth 33 km) which occurred on November 25, 2000 had a great influence to Apsheron and Baku, because of being near-field event (35 km to the south from Baku) with high magnitude and bigger effects. This earthquake was highly recommendable for selecting as “NEAR-EVENT”.

The other one should have been earthquake with far-event characteristics, with high magnitude and with influence to Apsheron and Baku. An earthquake, which occurred on January 27, 1963 (M=6.5, depth 55 km) is 100 km to the north from Baku [5]. The most important criteria used for picking up these two earthquakes were being on the seismically active zones with higher magnitude. The earthquake November 25, 2000 occurred on the South Apsheron Zone, whereas the earthquake January 27, 1963 occurred on the North Apsheron Zone. Thus, the following two earthquakes were utilized for estimation of the seismic motion at base rock in the next step.

Target Earthquakes:

NEAR-EVENT: M=6.5, Depth=35 km, 35 km to the South of Baku

FAR-EVENT: M=6.5, Depth=55 KM, 100 km to the North of Baku.

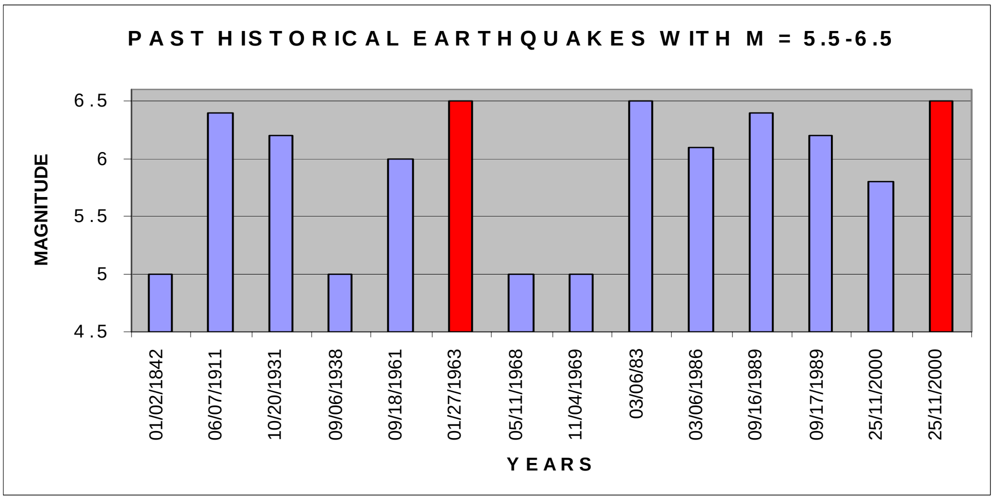

Figure 2. Past Historical Earthquakes

GROUND CONDITIONS OF STUDY AREA

After selecting target earthquakes it was reasonable to highlight target area in terms of geology, geomorphology, lithology and topography. Apsheron Peninsula was divided into 529 meshes, in the range of 50 km North to South and 76 km East to West. Each mesh was measured 2 km x 2 km. Using geomorphologic, geological and topographical map each mesh was researched by units of each map. The area was interpreted by overlapping those three maps using Map Info Professional 4.5 [6].

In terms of geomorphology, meshes are represented by marine deposits, deltaic valley plain, alluvial fan, sand dune, beach, abrasive, erosive accumulations, uplands, lowlands, plateaus, river channel. In addition to that, geomorphologic data shows that coastal side of Apsheron Peninsula including the capital of Azerbaijan, Baku city is situated below the sea level about 20-22 m, whereas the middle part and the areas off coastal side are elevated by 25 m upper the sea level.

From geological point of view, the study area lies in the southeastern part of Greater Caucasus. The oldest exposed formations are comprised of conglomerate, shale, marlstone of Paleogene period of Tertiary and then some formations of sandstone, shale, clayey limestone of Neogene period of Tertiary. Sand, gravel, clay, clayey sands of Pleistocene and Holocene epoch of Quaternary period represent the youngest exposed formations. Tectonically, the region is complicated by tectonic fractures, which can be divided into major (folded zones) and secondary fractures (mainly cross faults, which do not extend beyond one fold, and confined to their top potions).

In terms of topography, the study area is represented by a number of destinations and locations, such as mountains, plain areas, rivers, channels, salty lakes, sand shores, railway stations, cities, villages and living objects. Mostly western and southern-western part of Apsheron Peninsula is covered by mountains and mountainous areas with adjacent plain areas, as well, whereas, northern, northern-eastern and eastern part are represented by sand shores, lakes, rivers, gardens, forests and channels. Applying geological maps, it was necessary to determine surface geology that plays an important role in interpreting the site effects on ground shaking. For identifying surface geology, certain criteria was applied. That criteria was based on topography. For instance, in some meshes, there are, obviously, consequent outcrops of some formations of Pliocene and Miocene epoch underlying Quaternary soil types of formations. According to topographical data, villages, living objects, and small part of towns represent those meshes. Therefore, for those meshes it is highly significant to apply and consider Quaternary type of surface geology, bearing in mind the fact of risk for living objects (Table 1). As mentioned above, the study area was divided into rock outcrop and soil outcrop according to geological data and applying criteria. As a result, it was found out 213 meshes with rock outcrop and 316 meshes with soil outcrop. It was necessary to define amplification factor of the each geological unit for each mesh. Amplification was calculated through shear wave velocity of each geological unit (Midorikawa et al, 1994). In its turn, shear wave velocity (Vs) was defined from the formula (1).

$$Vs = Vp / (4.34-0.49 \cdot Vp), \quad (1)$$

where Vp – P-wave velocity (m/s).

The next important aspect was density value that was calculated based on the following approach (The Society of Exploration Geophysics of Japan, 1990):

Density for volcanic rocks: $0.3743 \cdot Vs+1.69$ (2)

Density for sedimentary rocks: $0.5415 \cdot Vs+1.50$ (3)

Quaternary type of deposits has been paid much attention to. According to geological map, geological crossection-profiles and boring data, the area with outcrop of Quaternary deposits was divided into 28 ground patterns. In this ground classification, the dynamic properties of ground layers are very effective and significant for estimation of the seismic motion (Table 2).

Table 1. Properties including dynamic for each soil and rock layer

ERA	PERIOD		EPOCH	Formation	Age Type	Geological Name	Characteristics	MARK	Maximum Thickness, m	Vs (m/s)	Density (g/cm3)	Amplification*	G/G0, h
Cenozoic	**Tertiary**	Paleogene	Paleocene-Eocene	Paleocene-Lower Eocene	P1-2	Conglomerate	Rock	**PAL**	**1500**	**1.15**	**2.13**	**0.67**	N/A
						Shale	Rock						
				Koun	P1-1	Marlstone	Rock						
			Oligocene	Maykop	P1-3	Sandstone	Rock						
		Neogene	Miocene	Tarkan Layer	N1-3	Sandstone	Rock	**NM**	**1200**	**0.99**	**2.04**	**0.72**	N/A
				Chokrag Layer		Tuff, breccia	Rock						
				Diatomic Suite		Shale, tuff, sandstone	Rock						
				Pontic Layer	N1-1	Conglomerate	Rock						
			Pliocene	Productive Layer	N	Clayey limestone	Rock	**NP**	**3800**	**0.59**	**1.95**	**0.90**	N/A
				Akchagil Layer	N1	Clayey sandstone	Rock						
				Apsheron Layer	N2	Clay, sandstone, tuff	Rock						
	Quaternary		Pleistocene	Urunji Layer	Q1	Sand & gravel	Stiff Soil	**QPLs/g**	**23**	**0.6**	**2.1**	**0.88**	N/A
					Q1	Clayey soil	Medium Soil	**QPLc**	**20**	**0.25**	**1.8**	**1.27**	c
			Pleistocene-Holocene	Lower Khvalin	Q2-3	Sandy soil	Stiff Soil	**QPLHs**	**7**	**0.5**	**2.0**	**0.95**	N/A
				Upper Khvalin	Q2-3	Clayey soil	Soft Soil	**QPLHc**	**5**	**0.1**	**1.6**	**1.86**	c
			Holocene	Modern Deposit	Q4	Ograric sands	Soft Soil	**QHorg**	**15**	**0.12**	**1.7**	**1.72**	s
					Q4	Clayey soil	Medium Soil	**QHc**	**7**	**0.15**	**1.7**	**1.57**	c
					Q4	Sandy soil, gravel	Meduim Soil	**QHs/g**	**4**	**0.35**	**1.9**	**1.10**	g

*Amplification related to the layer with Vs=440m/s

Table 2. Classification of Soil Types Ground Models

	TYPE				
Group	**A**	**B**	**C**	**D**	**E**
1	QH	QH	QH	QPLH	QPLH
2	(NM, NP, PAL)	QPLH	QPLH	(NP, NM)	QPL
3		(NP)	QPL		(NP, NM)
4			(NP, PAL)		

TYPE	A					
	A1	A2	A3	A4	A5	A6
1	QHorg 5 m	QHc 5m	QHs/g 7m	QHs/g 7 m	QHorg 7m	QHc 4 m
2	NM 1010 M	PAL 1500 m	PAL 1400 m	NP 1200m	NP 1050m	NP 1200m

TYPE	B					
	B1	B2	B3	B4	B5	B6
1	QHs/g 7m	QHc 5m	QHorg 10m	QHc 4m	QHs/g 5 m	QHorg 10m
2	QPLHc 5m	QPLHs 7m	QPLHs 7m	QPLHc 5m	QPLHc 5m	QPLHs 7m
3	NP 1960 m	NP 900 m	NP 1200m	NP 1100 m	NP 1200 m	PAL 1500 m

TYPE	C					
	C1	C2	C3	C4	C5	C6
1	QHs/g 4m	QHc 7m	QHorg 7m	QHs/g 7m	QHc 4m	QHorg 5m
2	QPLHc 5m	QPLHs 7m	QPLHs 7m	QPLHc 5m	QPLHs 7m	QPLHc 5m
3	QPLc 20m	QPLs/g 23m	QPLs/g 23m	QPLc 20m	QPLs/g 23m	QPLc 20m
4	NP 3800 m	NP 3000 m	NP 3200 m	NP 1500 m	PAL 1500m	NP 1910 m

TYPE	D			
	D1	D2	D3	D4
1	QPLHc 5m	QPLHs 7m	QPLHc 5 m	QPLHs 7m
2	NP 1200m	NM 400m	NM 400m	NP 1200m

TYPE	E					
	E1	E2	E3	E4	E5	E6
1	QPLHc 5m	QPLHs 7m	QPLHc 5m	QPLHs 7m	QPLHc 5m	QPLHs 7m
2	QPLc 23m	QPLs/g 20m	QPLc 23m	QPLs/g 20m	QPLc 23m	QPLs/g 20m
3	NM 1200m	NM 1200m	PAL 1500 m	PAL 1500 m	NP1390 m	NP 1390 m

CALCULATION OF SEISMIC MOTION AT ROCK LAYERS

After putting the epicenters of target earthquakes on the basemap, epicentral distance was calculated to each mesh for both events (Table 3). Then, giving the focal depth of each event, it was easy to determine the hypocentral distance.

Then, it was necessary to apply attenuation formula for calculating peak ground acceleration (PGA) at base rock [7]. As far as attenuation formula is concerned, there were many investigations of originality and applicability of proposed formula from Azerbaijan Republic. For providing exact comparisons between formulas of attenuation it was advisable to consider also the formula applying four directions from the epicentre (NW and SE – along the structure; NE and SW – across the structure) [8]. Main parameters are calculated for both NEAR and FAR-EVENTS, and related formulas are shown below

(4) and (5). Both formulas have usually been used for medium grounds of horizontal surface. Meanwhile,
it was recommendable to compare those formulas with attenuation formula for intra-plate earthquakes (6) used in Japan. The comparison (Figure 3) showed not so significant difference among them.

$$\text{Log } A = 0.80 \cdot M - 2.3 \cdot \text{Log } R + 0.80 \quad \text{for } A<160 \text{ cm/ s}^2 \text{ (for far-field event)} \tag{4}$$

$$\text{Log } A = 0.28 \cdot M - 0.8 \cdot \text{Log } R + 1.7 \quad \text{for } A>160 \text{ cm/ s}^2 \text{ (for near-field event)} \tag{5}$$

$$\text{Log } A = 0.50 \cdot Mw + 0.0043 \cdot H + 0.22 + 0.61 - \text{Log } (R + 0.0055 \cdot 10^{0.50 \cdot Mw}) - 0.003 \cdot R \tag{6}$$

Where
A – Peak Acceleration (gal)
M - Magnitude
R – Hypocentral Distance (km)
H – Focal Depth (km)
Mw – Moment Magnitude
Finally, using formula (4) and (5) for far-field and near-field event, respectively, PGA at base rock was calculated (Table 4). The calculations show that maximum value of PGA at base rock for the NEAR-EVENT reached 170 gal for the area with 25 km away from the epicenter. Whereas the minimum value for the same event was 49 gal for the area with 60 km away from the epicenter. As for the FAR-EVENT, the maximum value came to 27 gal for the area with its epicentral distance 78 km away from the epicenter. The minimum value of PGA reached 11 gal for the area with its epicentral distance 126 km away from the epicenter.
Then applying the following formula (7), amplification acceleration was calculated (Midorikawa et al, 1994)

$$\text{Log } ARA = 1.11 - 0.420 \cdot \text{Log } (AVS) \tag{7}$$

Where, ARA is the amplification of peak ground acceleration between target layer and the layer with Vs = 440 m/s, and AVS (m/s) is the average Vs among the layers between ground surface and 30 meters depth [9].
After identifying all above-mentioned parameters it was reasonable to calculate Peak Ground Acceleration at surface seismic motion by multiplication PGA at the base rock with amplification factor of the surface layers. But, this procedure concerned only for the meshes with rock outcrop. Quaternary outcrop needed careful and thorough attention. Surface motion for rock layers becomes input motion for Quaternary layers. Amplification for Quaternary was calculated by SHAKE program, one of the representatives One-Dimensional Equivalent Linear Ground Response Programs [10].

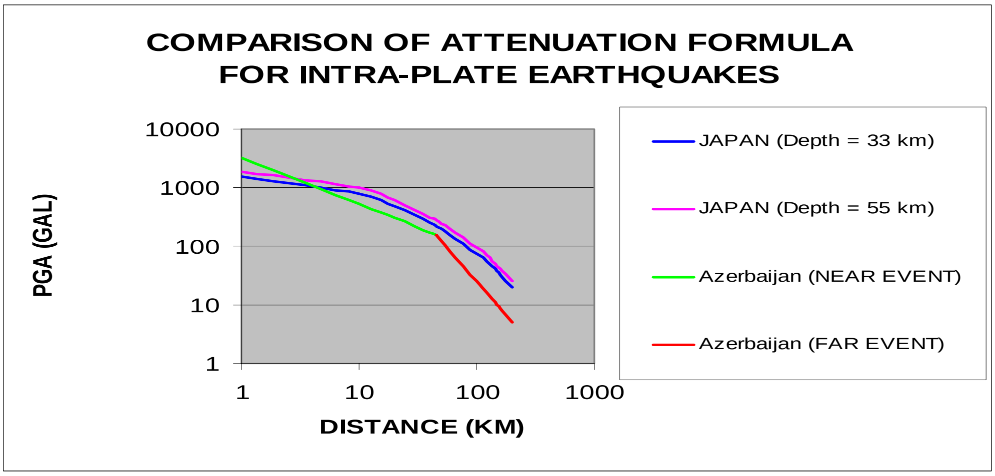

Figure 3. Comparison of Attenuation Formula

SURFACE SEISMIC MOTION FOR QUATERNARY DEPOSITS

For identifying surface seismic motion for Quaternary deposits, at first, it was important to examine all lithological units for classifying soil types of Quaternary deposits. Soil classifications have been conducted for broad evaluation of site effects. Another aspect used in classifying was geological crossection-profiles. Also, the boring data of measured shear-wave velocity data area was used to make the subsurface ground model for each mesh. These aspects helped very much in identifying soil types, their thickness, and the variations of underlying rock layers and the change of the thickness from place to place. According to surface geology with its shear wave velocity, thickness of the soil layers and depth of the base layers, proper soil pattern as representative of each mesh was decided. As a result of that research, the final table of ground modeling was obtained where soil properties including dynamic for each soil and rock layer were also shown (Table 1). Table 1 included also G/G0, h-shear strain relations given SHAKE program. Besides, ground model was classified into 28 ground patterns based on geomorphologic and geological data (Table 2). When the boring data is not available at all meshes, a technique for grouping of the meshes to a number of ground patterns was used, in addition to that, method of correlation of boring data was, also, used [11]. According to final ground modeling for Quaternary type of deposits, over the study area some formations of Pleistocene are not exposed, namely sandy gravel and clayey soil. Meanwhile, Lower Khvalin formation of Pleistocene is exposed with stiff sandy soil. As for Holocene formations, Upper Khvalin formation with soft clayey soil represents an outcrop together with organic soft soil, clayey medium soil and sandy gravel medium soil of Modern Deposits` formations of Holocene exposed (Table 2). It should be noted that the subsurface ground structure from surface to seismic bedrock at a site is modeled to the horizontally multi-layered structure with parameters of shear-wave velocity, thickness, density and damping factor of layers.

Based on previous studies, non-linear sire response has been discussed in geotechnical engineering, because laboratory tests show strong strain-dependent shear modulus of soils [11]. Several field studies find out evidence of non-linear behavior in observed motion records (i.e. Tokimatsu and Midorikawa, 1982; Chang et al., 1991). For providing non-linear analysis SHAKE program are widely utilized for calculation quasi-non-linear site effects [12].

Using SHAKE program, response values of the subsurface layers (acceleration and shear stress responses) were obtained by analyzing the input seismic motion to the base rock. This approach was based on the non-linear properties of the ground (the rigidity and damping factor of the ground change with the amount of shear strain generated during the earthquakes) [13]. Finally, using SHAKE program, seismic response analysis was performed for each ground pattern, and Peak Ground Acceleration of surface seismic motion was obtained for meshes with Quaternary surface geology.

The results of modeling for PGA cause by the NEAR-EVENT (Figure 4) were summarized as followings:

1) 200 to 300 gals of PGA, lower portion of IX of MSK scale, will appear at southern coast and surroundings of Baku City. This will cause severe damage to buildings there.

2) 100 to 200 gals of PGA, VIII of MSK scale, will appear most of the southern part of the Peninsula with Baku City and also including Mashtaga area. This will cause moderate damage there.

3) 50 to 100 gals of PGA, VII of MSK scale, will appear northern part of the Peninsula. This will cause slight influence there.

4) 35 to50 gals of PGA, upper portion of VII of MSK scale, will appear northern-western portions of the Peninsula.

For the FAR-EVENT results (Figure 5) were summarized as followings:

1) 50 to 70 gals of PGA, lower portion of VII of MSK scale, will appear northern part of the Peninsula including Mashtaga area.

2) 25 to 50 gals of PGA, VI of MSK scale, will appear middle to east part of the Peninsula.

3) 11 to25 gals of PGA, V of MSK scale, will appear most of the part of the Peninsula.

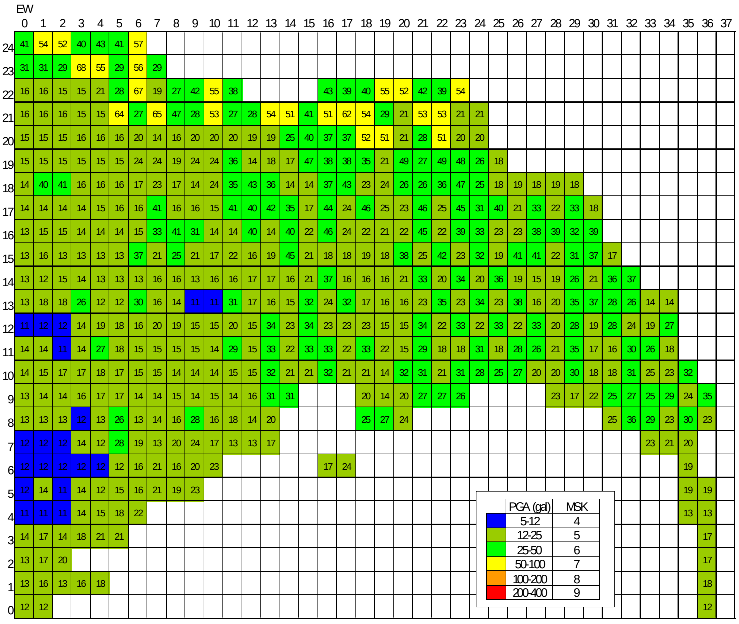

Figure 4. Map of PGA Value compared to MSK scale for the NEAR-EVENT.

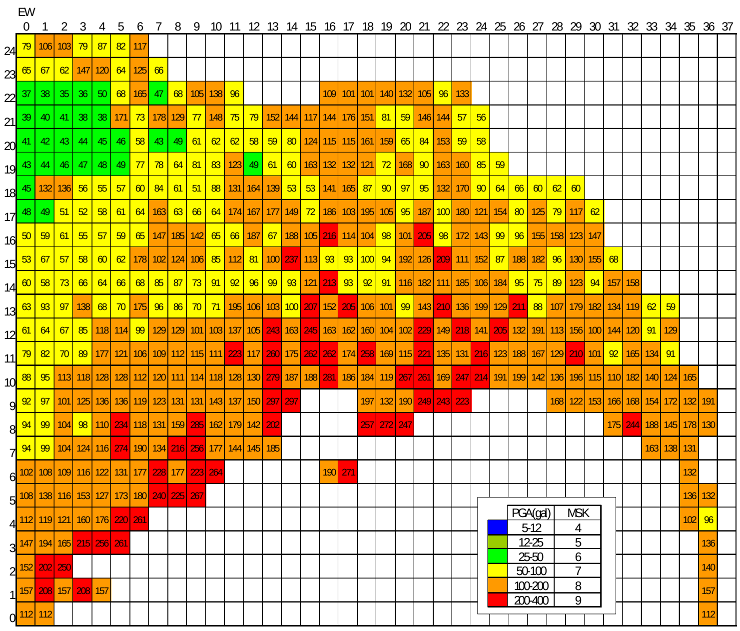

Figure 5. Map of PGA Value compared to MSK scale for FAR-EVENT.

Table 3. An example of Results of Mesh File including Mesh, Geollogy, Earthquakes, Distances, PGAs of the
EVENTS for the first 15 meshes.

			GEOLOGY		NOVEMBER 25, 2000 (M = 6.5, H = 33 km)					JANUARY 27, 1963 (M = 6.5, H = 55 km)				
M E S H			Model	Top Geol	Epicentral Distance	Hypocentral Distance	Base Rock PGA	Amplification	Surface PGA	Epicentral Distance	Hypocentral Distance	Base Rock PGA	Amplification	Surface PGA
N	SN	WE			KM	KM	GAL		GAL	KM	KM	GAL		GAL
1	0	36	B1	Q4	43.68	54.74	100.42	1.10	112.0	131.87	142.88	11.06	1.10	12.3
2	1	0	A4	Q4	33.11	46.74	144.42	1.10	156.7	126.61	138.04	11.97	1.10	13.0
3	1	1	A5	Q4	31.30	45.49	153.77	1.72	208.4	126.15	137.62	12.05	1.72	16.3
4	1	36	B2	Q4	44.27	55.22	98.45	1.57	157.0	129.97	141.13	11.37	1.57	18.1
5	2	0	A4	Q4	34.00	47.38	139.99	1.10	151.9	124.66	136.26	12.33	1.10	13.4
6	2	1	A5	Q4	32.25	46.14	148.80	1.72	201.6	124.20	135.83	12.42	1.72	16.8
7	2	2	A6	Q4	30.53	44.96	157.98	1.57	250.4	123.76	135.43	12.50	1.57	19.8
8	2	36	B1	Q4	44.94	55.76	96.27	1.10	139.6	128.08	139.39	11.70	1.10	17.0
9	3	0	A4	Q4	34.99	48.09	135.27	1.10	146.8	122.72	134.48	12.71	1.10	13.8
10	3	1	A5	Q4	33.29	46.87	143.51	1.72	194.5	122.25	134.05	12.80	1.72	17.3
11	3	2	A4	Q4	31.62	45.71	152.08	1.10	165.0	121.81	133.65	12.89	1.10	14.0
12	3	3	A5	Q4	30.00	44.60	158.69	1.72	215.0	121.40	133.27	12.97	1.72	17.6
13	3	4	A6	Q4	28.43	43.55	161.72	1.57	256.3	121.02	132.93	13.05	1.57	20.7
14	3	5	A6	Q4	26.91	42.58	164.68	1.57	261.0	120.67	132.61	13.12	1.57	20.8
15	3	36	B1	Q4	45.69	56.36	93.90	1.10	136.2	126.19	137.66	12.04	1.10	17.5

FOR BUILDING AND INFRASTRUCTURE DAMAGE ASSESSMENT

Seismic microzonation helps greatly in providing urban earthquake disaster prevention planning. As it is known, various physical parameters of ground motion relate to the collapse of buildings. For example, peak acceleration is directly associated with the damage to rigid bodies and buildings that have a high natural frequency, peak velocity is related to strain energy, causing the deformation of buildings already damaged. Those aspects connected to damage of building structures vary with structural types. On the other hand, seismic intensity is very comprehensive approach and measure of ground motion characteristics. Seismic intensity is very useful in regional damage analysis representing seismic severity in an affected area [14]. There are various seismic intensity scales used throughout the world for describing seismic intensity: MMI, MSK and JMA. In this paper, there was an attempt to apply the relationship between Peak Ground Acceleration value with MSK scale of seismic intensity.

Earthquake disaster mitigation, it its turn, requires disaster risk estimation technique and strategic risk management. It is very essential in constructing earthquake-resistant structures, to consider and investigate the damage behavior by destructive earthquake in detail and carefully examine the causes of damages. The major countermeasures are considered to be fire prevention, aseismic evaluation and reinforcement of public buildings against earthquake

The last strong earthquake in Baku (November 25, 2000) proved the fact that city is not fully ready for earthquake prevention. As a result of an earthquake, more than 1292 buildings were damaged, 3 buildings collapsed. Among them, there were brick buildings and houses constructed at the end of XIX and at the beginning of XX centuries. In addition to that, even recently constructed masonry and reinforced concrete 8 and 9-storeyed buildings had moderate damages after an earthquake. The effectiveness of the earthquake prevention was determined by the amount of avoidable damage. Such measures may prevent serious damage, but they cannot obviate minor damage completely. In some cases, an earthquake will have an intensity lower than that assumed when making the building earthquake proofing (for instance, an earthquake of intensity VII may occur in a seismic region with a rating of IX). There is another point that should be taken into account. If a building is reinforced to withstand earthquakes of intensity VIII and IX, then there will be no collapse of walls, ceilings, or other supporting structure. At the same time, some damage yet will occur, such as cracking of plaster, shifting of partitions, collapse of cornices, parapets, chimney stacks and cracking walls. The earthquakes January 23, 1967 and November 25, 2000 proved above-mentioned facts.

It should be noted that for disaster prevention countermeasures, analysis and evaluation of not only direct damages, but also the consequent reaction and the influence of the disaster are necessary [14]. Also essential aspects are efforts for combining damage results with emergency countermeasures and action plans for restoration. At the same time, lifeline facility and infrastructure play an essential role in earthquake prevention planning. Innovations in cities and lifeline facilities are efficient for daily life of the citizens by being equipped with high technology system, electric power and gas system supply. However, all above-mentioned aspects have weak points when it comes to disaster. One family of 5 people in Baku died from gas explosion as a result of gas leakage three days after the event. Another records show that two people died by falling-down the debris after a few weeks of an earthquake as a result of consequent aftershocks.

CONCLUSION

The comprehension of urban disaster and hazardous structures need special and careful attention for estimating earthquake disaster risk. Disasters which were not considered essential and were not previously seen important have lately become a significant issue when earthquakes happen in densely populated areas. The recent examples in Baku show that these damages are considerable since they influence citizens` life and lifeline system. Concerning seismic safety of structures, many problems exist in structural and non-structural members of the buildings in Baku. Besides, other types of disasters have happened in the center of the city or surrounding area, for instance, partial damage and falling-down of coverings of a structure, cracks and falling-down the window glass, falling-down the brick partitions and so on.

As a result of detailed research, the two maps of PGA value for both EVENTS were obtained. Due to the first map for the NEAR-EVENT (M=6.5 with depth of 33km), mostly the area of Apsheron Peninsula is covered with an intensity of VII, VIII and IX. In Baku, the intensity reached the value of IX and 297 gals of PGA around the center of Baku. That proves the fact that after a NEAR-EVENT occurred, Baku suffered severe damages with human losses. The other map for the FAR-EVENT shows that Apsheron Peninsula is covered by the intensity of V, VI and VII. Whereas in Baku, the intensity reached the point of VI and V. Again, it proved the fact that as a result of the FAR-EVENT, slight to moderate damages of buildings were estimated. There might be one conclusion that in the past, even though countermeasures and earthquake-resistant buildings` construction were considered important, disaster prevention countermeasures were not taken into consideration since they required an investment increase.

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