Research Note

Evaluation of A_a And A_v Coefficients in Iran for Limited Displacement Design Method of Retaining Walls

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ABSTRACT

The walls are permitted to displace to a specific amount in the seismic designing of the retaining walls using the limited displacement methods. As a result, the dynamic pressure of the earthquake on the retaining walls decreases compared to the case in which the wall is not allowed to move. The purpose of this paper is calculating the coefficients of the Richards and Elms equations in seismic designing of retaining walls, so that they can be applied in seismic provisions of Iran. Since this method requires determining the A_a and A_v coefficients, the records with the magnitude of higher than 5.5 were selected among the three-component records of the accelerograph network of the country. The baseline correction and filtering of all accelerograms have been conducted using SeismoSignal V.3.2.0 software. From a total of 426 records, a set of 142 records were selected with a distance to the epicenter less than 60 km and peak ground acceleration of more than 0.05 g (50 cm/sec^2). Since the results could be used in Iranian code, the macrozonation of A_a and A_v has been done throughout the country. Depending on the location of the accelerograph, the related records have been normalized according to the acceleration coefficients of the zone plan. Finally, a zoning map of A_a and A_v is proposed. Using this map and determining the permitted displacement, the designers can achieve the horizontal seismic coefficients for designing of retaining walls.

Keywords:
Retaining wall; Horizontal seismic coefficient; Limited displacement method; Processing the accelerograph records

1. Introduction

A retaining structure subjected to earthquake motion will vibrate with the backfill soil and the wall can easily move from the original position due to an earthquake. The pseudo-static methods cannot determine the maximum structure displacement. Therefore, many displacement methods have been presented independently or as various developed versions of the pseudo-static methods. In these methods, mostly based on the Newmark's sliding-block theory, the expected permitted displacement in the sliding soil mass is developed as a function of the soil mass critical acceleration and the seismic records parameters [1]. As shown in Figure 1 [2], Richards and Elms [3] have taken into consideration the wall inertia effect and concluded that there is some lateral movement of the wall even for mild earthquakes. It must be noted that the total displacement of a gravity retaining wall due to an earthquake does not all occur at once, but rather as a series of smaller displacement; provided, of course, that liquefaction conditions do not occur [4]. Using the M-O method and the Newmark's sliding-block analogy, Richards and Elms proposed a displacement-controlled method that incorporates basic ground motion parameters

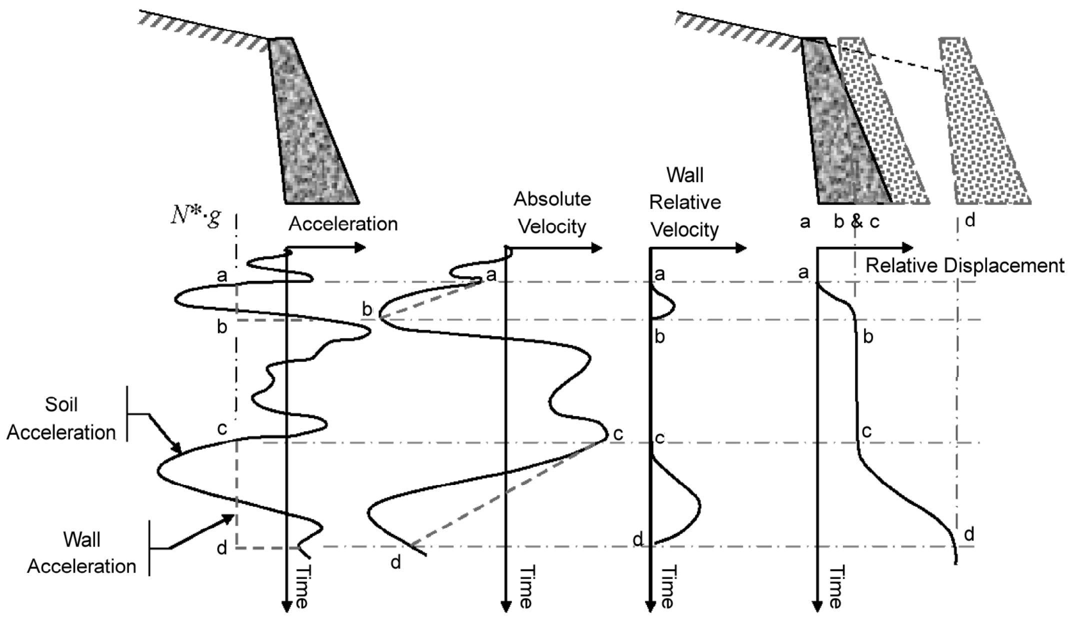

Figure 1. Incremental failures by base sliding [2].

(maximum acceleration and maximum velocity) and reduces the seismic soil pressure based on the acceptable amount of the wall movement.

In the Richards and Elms' [3] suggested method, it is supposed that the wall is permitted to displace to some specific extent, which in turn leads to decrease of horizontal acceleration coefficient, k_h, and as a result to decrease of pseudo-static forces exerted on the wall. They suggested Eq. (1) for computing the horizontal acceleration coefficient k_h.

$$k_h = A_a \left(\frac{0.2\, A_v^2}{A_a\, d} \right)^{1/4} \quad (1)$$

where A_a and A_v are effective acceleration coefficient and d is the permitted displacement in inches.

A_a and A_v have no obvious physical definitions. They have been proposed in building manuals determined by the ATC (Applied Technology Council, 1978). The effective peak acceleration coefficient, A_a, is numerically equal to the EPA when expressed as decimal fraction of gravity (i.e., A_a = 0.2 when EPA = 0.2g). The effective peak velocity-related acceleration coefficient, A_v, is numerically equal to EPV/30 when the EPV is expressed in in/sec (i.e., A_v = 0.2 when EPV = 6 in/sec). Note that A_v is an acceleration coefficient, even though it is obtained from the spectra velocity; it provides a useful measure of the longer-period (low-frequency) components of a ground motion.

The NEHRP Provisions use the effective peak acceleration (EPA) and effective peak velocity (EPV) to describe ground motions. These parameters can be thought of as normalizing factors for the development of smooth response spectra. The EPA was defined as the average spectral acceleration over the period range 0.1 to 0.5 sec divided by 2.5 (the standard amplification factor for a 5% damping spectrum), and the EPV was defined as the average spectral velocity at a period of 1 sec divided by 2.5. The process of averaging the spectral acceleration and velocities over a range of periods minimizes the influence of local spikes in the response spectrum on the EPA and EPV. The NEHRP provisions contain maps, based on probabilistic seismic hazard analyses with a 10% probability of exceeding in a 50-year period.

To apply the Richards and Elms [3] method in Iran, the A_a and A_v coefficients must be computed for the whole areas. According to the Iranian seismic building code, the acceleration coefficient as the design base is defined in specified seismic zone (Through the probabilistic seismic hazard analysis method and considering an earthquake probability of less than 10%, in a 50-year period). Therefore, it is more practical to define the computed coefficients in those seismic zones.

2. Records Selection

In order to accelograph analysis, the earthquake records with magnitude of higher than 5.5 were selected among the three-component records available on the country's accelerograph network (Building and Housing Research Center). The number of such recorded earthquakes in various organizations including the NEIC, ISC, IIEES, IGTU, and BHRC from 7th March 1976 to 1st December 2007 was 427 in total.

Local site conditions may affect important characteristics of the strong motions such as amplitude, frequency content and duration. Researches and the experiences of the previous earthquakes show that in the near fault zones, the changes in surface seismic characteristics are mostly independent on the site conditions, as the main reason of the changes is the orientation and direction of the wave propagation. Generally in zoning procedure, the sites are classified according to their distances from earthquake epicenter i.e. "near-field", and "far-field". There are contraries among the researchers on the definition of epicenter. There are proposals by some researchers based on past earthquakes, thus it seems the 50 km epicenter distance may be accepted as the distinctive boundary between two fields [5].

Since the main purpose of this research is zoning of the A_a and A_v quantities for the country, parameters such as frequency content and predominant period, together with PGA values are effective in selecting the accelerograph. We attempted to select the most effective and the strongest records in selected zones; therefore, 142 records were selected throughout the totally 427 records, with epicenter distances less than 60 km and the PGA higher than 0.05 m/s^2. The PGA values presented in Table (1) show the largest peak acceleration among the three components.

Table 1. Information of the selected stations and the result of the calculated A_a and A_v for different points.

No	Station	Record No.	Date Y/M/D	Tim h:m:s	Epic (Long.)	Epi (Lat.)	Focal Depth (km)	Epic Disp. (km)	Mag.	BHRC Soil Code	Hp (Hz)	Lp (Hz)	Div of A_a, A_v	*g	A_a	A_v
1	Bandarabbas3*	1006/01	1975/03/07	07:04:00	56.44	27.47	-	36	Ms6.1	IV-B	0.9	25	Zag	0.30	0.18	0.13
2	Qaen*	1043	1976/11/07	04:00:50	59.19	33.82	-	10	Ms6.4	II	0.25	25	F.M	0.35	0.27	0.22
3	Maku*	1046/01	1976/11/24	12:22:16	43.92	39.12	-	55	Ms7.3	I-A	0.8	25	Al	0.30	0.18	0.1
4	Maku*	1046/02	1976/11/24	12:36:48	44.2	39.1	63	35	mb5.5	I-A	1	25	Al	0.30	0.22	0.2
5	Bandarabbas3*	1050/01	1977/03/21	21:18:00	56.42	27.59	-	48	Ms6.9	IV-B	0.2	25	Zag	0.30	0.22	0.22
6	Bandarabbas4*	1051/01	1977/03/21	21:18:00	56.45	27.59	-	48	Ms6.9	IV-B	0.2	25	Zag	0.30	0.25	0.34
7	Bandarabbas4*	1051/02	1977/03/21	22:42:06	56.49	27.62	37	53	mb5.7	IV-B	0.9	25	Zag	0.30	0.25	0.16
8	Naqan*	1054/01	1977/04/06	13:36:00	50.76	31.9	-	5	Ms6.1	II-A	0.3	25	Zag	0.30	0.22	0.14
9	Deihuk*	1082/01	1978/09/16	15:35:57	57.44	33.37	34	10	Ms7.4	I	0.3	25	F.M	0.35	0.3	0.33
10	Boshruye*	1083/01	1978/09/16	15:35:57	57.44	33.37	34	55	Ms7.4	III-C	0.3	25	F.M	0.35	0.36	0.51
11	Tabas*	1084/01	1978/09/16	15:35:57	57.44	33.37	34	54	Ms7.4	II	0.4	25	F.M	0.35	0.28	0.19
12	Talesh*	1098/02	1978/11/04	15:22:20	48.9	37.67	-	14	Ms6	II-A	0.5	20	Al	0.30	0.15	0.09
13	Sarbaze*	1116/03	1979/01/10	15:05:44	61.02	26.48	3	28	Ms6.1	IV-C	1	25	F.M	0.30	0.26	0.13
14	Sade*	1106	1979/01/16	09:50:00	59.5	33.8	-	58	Ms6.8	III-C	0.55	25	F.M	0.35	0.23	0.14
15	Qaen*	1139	1979/11/27	17:10:33	59.63	34.05	-	52	Ms7.1	II	0.5	25	F.M	0.35	0.24	0.26
16	Khaf*	1143/04	1979/12/07	09:23:56	59.92	34.14	-	52	Ms6.1	-	0.9	19	F.M	0.30	0.24	0.11
17	Bonyabad*	1193/03	1979/12/07	09:23:56	59.92	34.14	-	8	Ms6.1	III-B	0.3	18	F.M	0.30	0.29	0.31
18	Delijan*	1157/01	1980/12/19	01:16:56	50.67	34.5	29	58	Ms5.8	III-B	0.25	25	Al	0.30	0.24	0.32
19	Urmia*	1188	1981/07/23	00:05:32	45.21	37.11	51	50	Ms5.5	IV-B	1	25	Al	0.30	0.21	0.1
20	Urmia*	1189	1981/07/23	00:05:32	45.21	37.11	51	50	Ms5.5	IV-B	1	25	Al	0.30	0.28	0.14
21	Golbaf*	1176/05	1981/07/28	17:22:23	57.77	29.99	11	13	Ms7	III	0.35	25	F.M	0.35	0.27	0.25
22	Bastam*	1279	1985/10/29	13:13:40	54.81	36.75	13	34	Ms6	III-B	1	25	Al	0.30	0.18	0.1
23	Fathabad*	1270/02	1986/05/02	03:18:37	53.32	28.02	27	49	Ms5.1	III-C	0.9	25	Zag	0.30	0.22	0.12
24	Bandarabbas4*	1309	1987/04/29	01:45:25	56.13	27.43	27	32	Ms5.4	IV-B	0.9	25	Zag	0.30	0.18	0.17
25	Nurabad Mamasani*	1329	1988/12/06	13:20:42	51.64	29.92	17	24	Ms5.6	III-C	0.8	25	Zag	0.30	0.16	0.12
26	Dogonbadan*	1389/01	1989/05/27	20:08:37	50.88	30.13	33	26	Ms5.7	III-C	0.8	25	Zag	0.30	0.21	0.17
27	Golbaft*	1346/01	1989/11/20	04:19:05	57.72	29.88	18	0	Ms5.7	III	0.3	20	F.M	0.35	0.23	0.32
28	Siraj*	1347/04	1989/11/20	04:19:05	57.72	29.88	18	38	Ms5.7	II	0.9	25	F.M	0.35	0.25	0.19
29	Polsefid*	1373	1990/01/20	01:27:10	53	35.89	25	26	Ms5.8	II-B	0.6	18	Al	0.30	0.29	0.08
30	Abbar*	1362/01	1990/06/20	21:00:11	49.41	36.96	18	41	Ms7.7	I	1	25	Al	0.35	0.14	0.16
31	Firuzabad*	1486	1994/03/01	03:49:00	52.61	29.09	12	29	Ms6	I	0.6	25	Zag	0.30	0.27	0.12
32	Firuzabad*	1489/01	1994/03/30	19:55:42	52.74	28.99	53	25	mb5.5	I	0.6	25	Zag	0.30	0.29	0.11
33	Zarat	1492/06	1994/03/30	19:55:48	52.74	28.99	53	16	mb5.5	I	0.3	35	Zag	0.30	0.24	0.08
34	Meimand*	1490/02	1994/06/20	09:09:02	52.61	28.96	8	17	Ms5.7	II	1	18	Zag	0.30	0.14	0.08
35	Zarat	1492/16	1994/06/20	09:09:02	52.61	28.96	8	27	Ms5.7	I	0.3	35	Zag	0.30	0.21	0.11
36	Firuzabad	1493/02	1994/06/20	09:09:02	52.61	28.96	8	14	Ms5.7	I	0.3	35	Zag	0.30	0.16	0.09
37	Zanjiran	1502/09	1994/06/20	09:09:02	52.61	28.96	8	12	Ms5.7	II	0.35	35	Zag	0.30	0.16	0.04
38	Ashkhane	1659/02	1997/02/04	10:37:47	57.29	37.66	10	35	Ms6.8	-	0.2	25	Al	0.30	0.36	0.27
39	Raz	1676/02	1997/02/04	10:37:47	57.29	37.66	10	35	Ms6.8	III-C	0.4	30	Al	0.30	0.36	0.14
40	Gifan*	1726/02	1997/02/04	10:37:47	57.29	37.66	10	31	Ms6.8	III-B	0.6	25	Al	0.30	0.21	0.19
41	Bojnurd*	1727/02	1997/02/04	10:37:47	57.29	37.66	10	20	Ms6.8	III-B	0.6	25	Al	0.30	0.16	0.08
42	Robat*	1728/02	1997/02/04	10:37:47	57.29	37.66	10	44	Ms6.8	IV-B	0.6	20	Al	0.30	0.21	0.24
43	Ardabil 1	1693/01	1997/02/28	12:57:45	48.06	38.07	10	26	Ms6.1	III-B	0.15	30	Al	0.30	0.21	0.25

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No	Station	Record No.	Date Y/M/D	Tim h:m:s	Epic (Long.)	Epi (Lat.)	Focal Depth (km)	Epic Disp. (km)	Mag.	BHRC Soil Code	Hp (Hz)	Lp (Hz)	Div of A_a, A_v	*g	A_a	A_v
44	Ardabil 2	1701/01	1997/02/28	12:57:45	48.06	38.07	10	24	Ms6.1	III-B	0.1	30	Al	0.30	0.22	0.18
45	Nayyer	1689/04	1997/02/28	12:57:45	48.06	38.07	10	5	Ms6.1	IV-C	0.3	30	Al	0.30	0.19	0.09
46	Namin	1724	1997/02/28	12:57:45	48.06	38.07	10	54	Ms6.1	III-C	0.8	35	Al	0.30	0.16	0.04
47	Sarab	1725	1997/02/28	12:57:45	48.06	38.07	10	48	Ms6.1	–	0.1	25	Al	0.30	0.21	0.18
48	Helabad*	1733	1997/02/28	12:57:45	48.06	38.07	10	36	Ms6.1	–	0.35	25	Al	0.30	0.32	0.21
49	Kariq	1833/02	1997/02/28	12:57:45	48.06	38.07	10	17	Ms6.1	–	0.2	20	Al	0.30	0.17	0.05
50	Qasemabad	1754/01	1997/05/10	07:57:29	59.8	33.82	10	60	Ms7.3	–	0.35	35	F.M	0.30	0.23	0.18
51	Siraj*	1913/01	1998/03/14	19:40:27	57.61	30.15	9	7	Ms6.9	II	0.35	25	F.M	0.35	0.35	0.37
52	Garmi	2008/01	1998/07/09	14:19:18	48.51	38.72	26	54	mb5.9	–	0.15	35	Al	0.30	0.28	0.15
53	Namin	2027/01	1998/07/09	14:19:18	48.51	38.72	26	33	mb5.9	III-C	0.3	45	Al	0.30	0.23	0.1
54	Razi	2033/01	1998/07/09	14:19:18	48.51	38.72	26	37	mb5.9	–	0.15	30	Al	0.30	0.2	0.17
55	Baladeh	2131/02	1999/05/06	23:00:53	51.88	29.5	33	24	Ms6.3	–	0.1	35	Zag	0.30	0.36	0.24
56	Khanzeinan	2130/01	1999/05/06	23:00:53	51.88	29.5	33	32	Ms6.3	III-A	0.1	30	Zag	0.30	0.26	0.11
57	Salehabad	2221/01	1999/11/08	21:37:23	61.21	35.73	–	12	Ms5.2	–	0.2	25	Al	0.30	0.14	0.06
58	Siahu	2325/01	2000/03/05	09:40:06	56.47	27.95	33	25	Ms5.3	–	0.25	35	Zag	0.30	0.23	0.05
59	Ahmadi	2510/01	2000/03/05	09:40:06	56.47	27.95	33	30	Ms5.3	–	0.1	35	Zag	0.30	0.2	0.1
60	Avaj	2749/01	2002/06/22	02:58:20	49.02	35.71	–	23	Ml6.2	I	0.15	40	Al	0.30	0.27	0.12
61	Razan	2756/01	2002/06/22	02:58:20	49.02	35.71	–	35	Ml6.2	–	0.15	40	Al	0.30	0.29	0.19
62	Abgarm	2748/01	2002/06/22	02:58:20	49.02	35.71	–	24	Ml6.2	III	0.1	25	Al	0.30	0.34	0.19
63	Abhar	2763	2002/06/22	02:58:20	49.02	35.71	–	52	Ml6.2	III	0.1	25	Al	0.30	0.19	0.36
64	Darsjin	2769/02	2002/06/22	02:58:20	49.02	35.71	–	40	Ml6.2	II	0.2	30	Al	0.30	0.27	0.16
65	Shirinsu	2781	2002/06/22	02:58:20	49.02	35.71	–	57	Ml6.2	–	0.1	20	Al	0.30	0.21	0.19
66	Masjedsoleiman Dam2	2877/01	2002/09/25	22:28:15	49.4	32.1	–	6	Ml5.5	–	0.1	30	Zag	0.30	0.12	0.06
67	Masjedsoleiman	2873	2002/09/25	22:28:15	49.4	32.1	–	19	Ml5.5	–	0.2	40	Zag	0.30	0.23	0.1
68	Sargaz-Ahmadi	3198/01	2003/02/14	10:28:58	57	28.14	9	40	Ml6.1	–	0.1	40	Zag	0.30	0.15	0.04
69	Hajiabad	3040/01	2003/07/10	17:06:37	54.1	28.17	10	37	Ml6.1	–	0.1	40	Zag	0.30	0.22	0.13
70	Javim	3041/01	2003/07/10	17:06:37	54.1	28.17	10	15	Ml6.1	–	0.15	30	Zag	0.30	0.22	0.23
71	Hajiabad	3040/03	2003/07/10	17:40:15	54.2	28.21	14	27	Ml6.3	–	0.15	40	Zag	0.30	0.3	0.12
72	QaraZiaeddin	3055	2003/08/11	20:12:08	44.94	38.89	14	7	Ml5.8	–	0.2	30	Al	0.30	0.31	0.18
73	Dobaran	3136/05	2003/11/28	23:19:46	54.14	28.44	10	5	Ml5.5	–	0.1	35	Zag	0.30	0.17	0.12
74	Mohamadabad Maskun	3162/01	2003/12/26	01:56:56	58.4	29.21	–	60	6.3	II	0.1	40	F.M	0.30	0.31	0.16
75	Bam 1	3168/02	2003/12/26	01:56:56	58.4	29.21	–	14	6.3	–	0.1	40	F.M	0.30	0.25	0.3
76	Abaraq	3176/01	2003/12/26	01:56:56	58.4	29.21	–	47	6.3	–	0.25	40	F.M	0.30	0.11	0.06
77	Abad	3239/01	2004/03/02	07:51:47	51.32	29.01	30	6	Ml5.8	II	0.25	40	Zag	0.25	0.22	0.08
78	Ahrom	3241	2004/03/02	07:51:47	51.32	29.01	30	14	Ml5.8	I	0.35	35	Zag	0.25	0.1	0.04
79	Alihosseini	3244/02	2004/03/02	07:51:47	51.32	29.01	30	29	Ml5.8	II	0.25	45	Zag	0.25	0.13	0.03
80	Bushehr 5	3235	2004/03/02	07:51:47	51.32	29.01	30	50	Ml5.8	–	0.2	30	Zag	0.25	0.06	0.02
81	Delvar	3236	2004/03/02	07:51:47	51.32	29.01	30	37	Ml5.8	III	0.2	25	Zag	0.25	0.13	0.05
82	Sa'dabad	3237	2004/03/02	07:51:47	51.32	29.01	30	46	Ml5.8	I	0.15	30	Zag	0.25	0.08	0.03
83	Borazjan	3242/02	2004/03/02	07:51:47	51.32	29.01	30	29	Ml5.8	II-B	0.25	30	Zag	0.25	0.09	0.03
84	TangeEram	3268/02	2004/03/02	07:51:47	51.32	29.01	30	26	Ml5.8	II	0.25	45	Zag	0.25	0.14	0.07
85	Taleghan	3318	2004/05/28	12:38:46	51.32	36.45	40	58	mb6.2	II	0.1	35	Al	0.30	0.25	0.6
86	Garmabdar	3326	2004/05/28	12:38:46	51.32	36.45	40	59	mb6.2	–	0.1	20	Al	0.30	0.25	0.1
87	Pul	3330/01	2004/05/28	12:38:46	51.32	36.45	40	24	mb6.2	–	0.1	35	Al	0.30	0.17	0.05
88	Hassan Kif	3333	2004/05/28	12:38:46	51.32	36.45	40	16	mb6.2	III	0.25	45	Al	0.30	0.18	0.08
89	Amirkabir Dam 2	3364/01	2004/05/28	12:38:46	51.32	36.45	40	59	mb6.2	–	0.2	30	Al	0.30	0.28	0.09
90	Noshahr	3368/01	2004/05/28	12:38:46	51.32	36.45	40	27	mb6.2	IV	0.1	18	Al	0.30	0.31	0.17
91	Pul	3330/12	2004/05/29	09:23:47	51.29	36.37	20	27	Ml5.8	–	0.15	25	Al	0.30	0.15	0.07
92	Balade	3432/01	2004/05/29	09:23:47	51.29	36.37	20	50	Ml5.8	–	0.25	30	Al	0.30	0.24	0.07
93	Mohamadabad Maskun	3555/01	2004/10/06	11:14:37	57.98	28.81	–	14	Ml5.7	II	0.2	35	F.M	0.30	0.21	0.07
94	Jiroft Dam 2	3743/02	2004/10/06	11:14:37	57.98	28.81	12	50	Ml5.7	–	0.2	20	F.M	0.30	0.26	0.12
95	Aliabad	3542	2004/10/07	21:46:18	54.29	37.14	38	56	Ml6.2	–	0.25	20	Al	0.30	0.29	0.14
96	Gorgan	3545	2004/10/07	21:46:18	54.29	37.14	38	35	Ml6.2	II-A	0.2	20	Al	0.30	0.2	0.08
97	Gomishan	3546	2004/10/07	21:46:18	54.29	37.14	38	20	Ml6.2	–	0.15	35	Al	0.30	0.3	0.16
98	Abqala	3556/01	2004/10/07	21:46:18	54.29	37.14	38	21	Ml6.2	–	0.15	30	Al	0.30	0.28	0.21
99	Bandargaz	3557/02	2004/10/07	21:46:18	54.29	37.14	38	52	Ml6.2	–	0.3	20	Al	0.30	0.25	0.09
100	Incheborun	3560/01	2004/10/07	21:46:18	54.29	37.14	38	52	Ml6.2	–	0.2	20	Al	0.30	0.31	0.12
101	Kosar Dam	3561/01	2004/10/07	21:46:18	54.29	37.14	38	43	Ml6.2	–	0.25	20	Al	0.30	0.19	0.11
102	Saddoshemgir	3562/01	2004/10/07	21:46:18	54.29	37.14	38	40	Ml6.2	–	0.1	40	Al	0.30	0.24	0.19
103	Gomishan	3607	2005/01/10	18:47:30	54.541	37.123	–	42	Ml6.1	–	0.15	30	Al	0.30	0.26	0.08
104	Aqala	3608	2005/01/10	18:47:30	54.541	37.123	–	14	Ml6.1	–	0.15	35	Al	0.30	0.27	0.14
105	Incheborun	3618	2005/01/10	18:47:30	54.541	37.123	–	40	Ml6.1	–	0.15	35	Al	0.30	0.22	0.09
106	Gorgan	3623	2005/01/10	18:47:30	54.541	37.123	–	34	Ml6.1	II-A	0.15	35	Al	0.30	0.25	0.11
107	Kosar Dam	3638	2005/01/10	18:47:30	54.541	37.123	–	35	Ml6.1	–	0.2	20	Al	0.30	0.23	0.11
108	Catrud	3660/01	2005/02/22	02:25:26	56.9	30.79	–	21	6.4	II	0.1	20	F.M	0.30	0.3	0.38

Table 1. Information of the selected stations and the result of the calculated A_a and A_v for different points.

No	Station	Record No.	Date Y/M/D	Tim h:m:s	Epic (Long.)	Epi (Lat.)	Focal Depth (km)	Epic Disp. (km)	Mag.	BHRC Soil Code	Hp (Hz)	Lp (Hz)	Div of A_a, A_v	*g	A_a	A_v
109	Ravar	3661	2005/02/22	02:25:26	56.9	30.79	-	54	6.4	-	0.15	30	F.M	0.30	0.33	0.32
110	Zarand	3671/01	2005/02/22	02:25:26	56.9	30.79	-	31	6.4	III	0.1	30	F.M	0.30	0.23	0.24
111	Hinman	3679	2005/02/22	02:25:26	56.9	30.79	-	47	6.4	-	0.1	25	F.M	0.30	0.23	0.2
112	Dashtekhak	3686	2005/02/22	02:25:26	56.9	30.79	-	45	6.4	-	0.15	30	F.M	0.30	0.31	0.15
113	Qadruni Dam	3689/01	2005/02/22	02:25:26	56.9	30.79	-	21	6.4	-	0.2	30	F.M	0.30	0.21	0.18
114	Shirinrud Dam 1	3697/01	2005/02/22	02:25:26	56.9	30.79	-	13	6.4	II	0.1	30	F.M	0.30	0.15	0.12
115	Sibsavaran	3722	2005/03/13	03:31:23	62.06	26.79	-	55	5.9	-	0.15	30	F.M	0.30	0.27	0.1
116	Bahaabad	3760	2005/05/14	18:04:54	56.83	30.69	10	21	mb5.5	-	0.2	33	F.M	0.30	0.29	0.2
117	Khanuk	3778/06	2005/05/14	18:04:54	56.83	30.69	10	6	mb5.5	-	0.15	45	F.M	0.30	0.15	0.07
118	Shirinrud Dam 1	3785/04	2005/05/14	18:04:54	56.83	30.69	10	23	mb5.5	II	0.15	35	F.M	0.30	0.24	0.1
119	Suza	3915/01	2005/11/27	10:22:23	55.76	26.82	-	31	5.9	-	0.1	45	Zag	0.30	0.23	0.07
120	Suza	3915/07	2005/11/27	16:30:38	55.7	26.77	-	37	5.5	-	0.2	30	Zag	0.30	0.23	0.1
121	Kashkuye	3984	2006/02/18	11:03:36	55.86	30.72	22	30	Ml5.5	-	0.2	25	F.M	0.30	0.16	0.06
122	Rafsanjan	3987	2006/02/18	11:03:36	55.86	30.72	22	37	Ml5.5	III-C	0.2	40	F.M	0.30	0.26	0.1
123	Sargaz-Ahmadi	3996/02	2006/02/28	07:31:03	56.91	28.26	14	43	Ml6.1	-	0.2	40	F.M	0.30	0.22	0.14
124	Soqan	3998	2006/02/28	07:31:03	56.91	28.26	14	10	Ml6.1	-	0.2	25	F.M	0.30	0.31	0.3
125	Rezvan	4012/01	2006/03/25	07:28:54	55.69	27.57	14	38	Ml5.5	-	0.15	45	Zag	0.30	0.19	0.06
126	Fin	4013/01	2006/03/25	07:28:54	55.69	27.57	14	21	Ml6	IV-B	0.1	45	Zag	0.30	0.28	0.07
127	Chalanchulan	4027/02	2006/03/30	16:17:06	48.97	33.61	8	8	Ml5.7	-	0.15	40	Zag	0.35	0.23	0.13
128	Chalanchulan	4027/05	2006/03/30	19:36:16	48.95	33.69	9	5	Ml5.7	-	0.1	45	Zag	0.35	0.26	0.46
129	Chalanchulan	4027/08	2006/03/31	01:17:02	49	33.69	9	9	Ml6.2	-	0.15	25	Zag	0.35	0.24	0.27
130	Toshakabsard	4035/03	2006/03/31	01:17:02	49	33.69	9	41	Ml6.2	-	0.15	35	Zag	0.35	0.19	0.06
131	Chaqlundi	4018/03	2006/03/31	01:17:02	49	33.69	9	41	Ml6.2	-	0.15	25	Zag	0.35	0.36	0.45
132	Dareasbar	4052/03	2006/03/31	01:17:02	49	33.69	9	27	Ml6.2	-	0.2	30	Zag	0.35	0.27	0.1
133	Toshakabsard	4035/06	2006/03/31	11:54:02	48.8	33.79	14	21	Ml5.6	-	0.3	40	Zag	0.35	0.1	0.03
134	Bam	4289	2007/03/26	06:36:53	58.4	29.2	10	14	Ml5.5	-	0.25	30	F.M	0.25	0.1	0.03
135	Baravat	4298/01	2007/03/26	06:36:53	58.4	29.2	10	14	Ml5.5	-	0.35	45	F.M	0.25	0.13	0.04
136	Poshtrud	4305/02	2007/03/26	06:36:53	58.4	29.2	10	9	Ml5.5	-	0.4	20	F.M	0.25	0.11	0.03
137	Kahak	4348	2007/06/18	14:29:49	50.91	34.54	7	16	Ml5.7	-	0.2	25	Al	0.30	0.15	0.05
138	Gazran	4350	2007/06/18	14:29:49	50.91	34.54	7	45	Ml5.7	-	0.2	25	Al	0.30	0.22	0.13
139	Panzdah Khordad Dam2	4379	2007/06/18	14:29:49	50.91	34.54	7	57	Ml5.7	-	0.25	30	Al	0.30	0.22	0.05
140	Tabriz 6	4509/02	2007/12/01	18:45:11	46.43	38.13	22	13	Ml5.5	-	0.2	45	Al	0.35	0.14	0.05
141	Basmang	4502/02	2007/12/01	18:45:11	46.43	38.13	22	15	Ml5.5	-	0.3	25	Al	0.35	0.22	0.09
142	Tabriz 4	4504/02	2007/12/01	18:45:11	46.43	38.13	22	13	Ml5.5	III-C	0.2	35	Al	0.35	0.23	0.08

Error in baseline of accelerograph records, particularly when they are achieved by analogue devices is expected. The errors lay generally in frequency range of higher than 20 Hz and lower than 0.5 Hz where they must be corrected as much as possible. The high frequency error may affect the estimate of maximum acceleration in high period range. However, the low frequency error may affect time-series of velocity and displacement achieved throughout the integration. Figure (2) shows the effect of aforementioned two error samples on the main waves.

High and low error frequency selection is a cause of omission of the earthquake real physical waves from the accelerograph during processing operations or it may delete the high and low frequency errors totally from the accelerograph. In both cases, the context value of the accelerograph reduces and the resulted accelerograph does not show the real motion of the earth, anymore. In fact, in this way, we choose to have data in a limited frequency and with a specific preciseness rather than in higher and lower frequencies that increases the possibility of the great errors.

There are two predominate and common methods to correct the accelerograph records: signal to noise (S/N) and the Fourier standard shape. Although the S/N signaling method is useful, its results are severely subordinate to selection of the signal and noise windows.

When it is difficult to distinguish signal and noise, applying the S/N method is not practical; also, difference in windows length leads to various spectrum characteristics between signal and noise. Any change in one of them changes the S/N relatively. Therefore, the achieved results would not be reliable

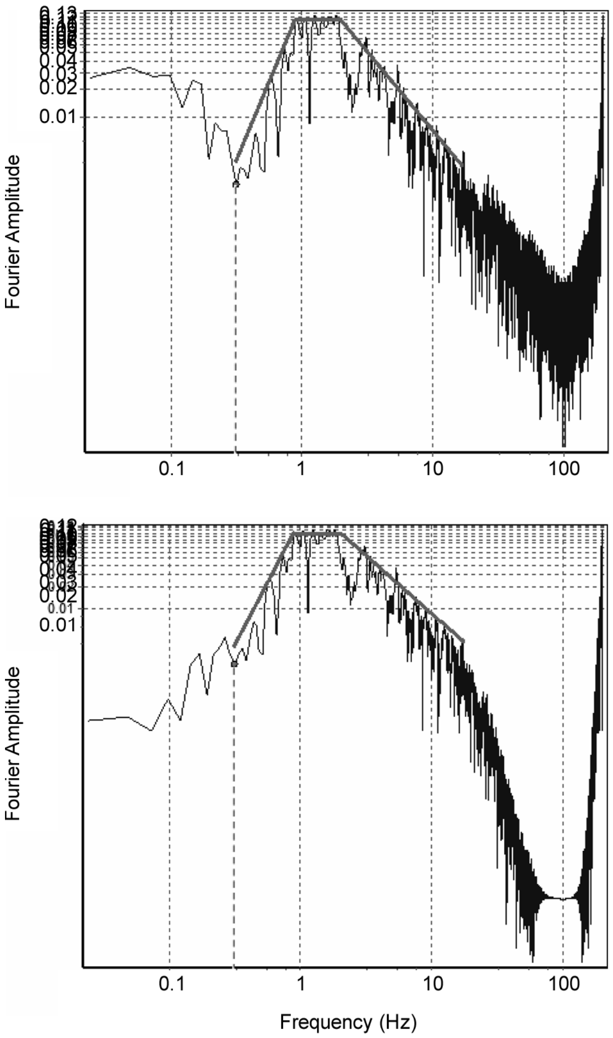

Figure 2. Two error samples' effecting the main waves.

all over the frequency limits. At the same time, the noise window must be selected in pre-event section, to be acceptable.

It is not possible actually for the records registered by the analogue systems and by the far seismic accelerograph (with regard to the pre-event memory time). In cases of short time-lag to P wave arrival; it is not possible to have an appropriate noise window. As S/N method contains limitations depend on the earthquake distance, the seism duration and the noise level, in this research, the Fourier standard shape has been used to determine the filtered frequencies.

In theoretical shape of the far field Fourier acceleration spectrum, a ω^2 increase is expected in the region below the 'corner frequency' (f_c) and a decaying shape at high frequencies beyond the 'maximum frequency' ($f_{\max}$) with a plateau in between. Relatively constant amplitude of the FFT spectrum at frequencies lower than f_c or at frequencies beyond $f_{\max}$ is generally an indication of large low or high-frequency noise, respectively. At the beginning of the ascending section and at the end of the descending section, the spectrum range is more or less the same. They show the low and high noise frequency, respectively, and specify the high and low limits of the filter $[F_{HP}, F_{LP}]$. After filtering and appearance of the velocity and displacement time series, the filter reliability is evaluated to be sure about the results correctness at this stage.

In this research, the same processing program is used for all the applied data. Although some accelerograph records have been registered by the analogue devices and their processing is too complicated, they were digitized earlier in the accelerograph network of the Building and Housing Research Center and all files were V1 files which were digitized and corrected, using the related units. Therefore, processing were exactly the same.

The available digital accelerograph records were processed using Seismo Signal V3.2.0 software and the fourth order middling Butterworth filter. This software has some instructions for various operations error, such as: correcting the baseline and displacement throughout the integration of the corrected accelerograph and calculating Fourier and response spectrum.

3. Accelerographs' Record Processing

Digitization is the first step of the analog accelerograph using procedure. Each record is converted into appropriate (.tif) image files using an A4 scanner. The scanning resolution is determined based on studying the record spectrum containing 300, 600 and 1200 dpi. At the second stage of the digitization, the (.tif) raster files are converted to vector format using the Kinemetrics Scan View software (KINEMETRICS, 1990). The procedure involves record selection, baseline determination (usually a fixed trace) and correction. Data processing relates to the generation of the corrected data out of the processing the digitized records. Each digitized record is processed through considering the recording instrument parameters. The original data are produced and usually referred to as V1 files.

The baseline correction is the first correction usually applied in the digitized records. Baseline errors are mostly due to the film deformation and other similar recording problems, which result in low frequency noise. Generally, a small shift in the accelerograph's waveform baseline produces a false linear trend in the velocity's waveform baseline and a second order term trend in displacement. A simple technique to overcome this problem is its subtraction from the acceleration waveforms of a straight line calculated by the least squares method.

The errors may affect the records and must be corrected or at least suppressed, especially when they appeared from the analogue instruments as the most prominent in the high frequency (20Hz) and low frequency (0.5Hz) ranges. In order to correct the short and long period errors, the accelerograph records' time-series are often filtered. Many different types of filter have been used to filter the records such as Ormsby filters, frequency-domain filters, elliptical filters and Butterworth filters. Filtering will overcome the errors in the stop bands; however, it ignores any ground motions within the time series and hence outside the pass band the corrected accelerogram can no longer be expected to adequately represent the true ground motion. Of course, usually, the stop bands adopted are outside the range of engineering interest. The choice of the low-frequency cut-off often has a considerable effect on long-period time-domain parameters such as peak ground velocity (PGV) and peak ground displacement (PGD). Hence, such parameters are associated with much uncertainty unless these cut-off frequencies were selected carefully. It should be noted that low frequency seismic waves have a great contribution in the reaction of high buildings and huge constructions such as bridges and dams. Therefore, they are of great importance for engineering seismology.

Various software have been used in digital seismology, including SeismoSignal which provides an easy and efficient way of processing seismic data and deriving a number of parameters often required by seismologists and earthquake engineers. We have decided to use this program in set different filter configurations and to evaluate the obtained seismic parameters.

Estimation of the Fast Fourier Transformation is the next step of the uncorrected data processing, for the frequencies up to 30 Hz. In theoretical shape of the far field Fourier acceleration spectrum, a ω^2 increase is expected in the region below the 'corner frequency' (f_c) and a decaying shape at high frequencies beyond the 'maximum frequency' ($f_{\max}$) with a plateau in between. Relatively constant amplitude of the FFT spectrum at frequencies lower than f_c or at frequencies beyond $f_{\max}$ is generally an indication of large low or high frequency noise, respectively. The fast Fourier transformation (FFT) is computed in SeismoSignal. The reliable frequency band is determined and checked for the spectrum shape. Band pass filtering allows signals within a given frequency range (F_{HP} to F_{LP}) bandwidth to pass through. The band pass is filtered with a Butterworth filter of order 4. Butterworth filter is chosen since it has a fairly sharp transition from pass band to stop band, and it has a moderate group delay response. Applying the previously calculated filters, we obtained the corrected data usually referred to V2 files.

4. Determining A_a and A_v for Seismic Zones of Iran

The purpose of this research is determining coefficients applicable in Iranian building code. According to this code, seismic hazard predicting is derived from specified seismic zones (through probable seismic hazard analyses and considering a 10% occurring probability in a 50-year period). It is attempted to study geo-structure characteristics, earthquake co-acceleration maps, the importance of cities and population density in such way. Therefore, depending on the different areas, the related design acceleration coefficients have been normalized [6].

Regarding the earthquake parameters (duration, frequency content etc.) affecting the A_a and A_v values, zoning should be conducted, thus the earthquake with the same nature set in the same area. There are three active seismic zones in Iran: Alborz, Zagros, and central Iran, see Figure (3) [7]. According to the Iran zoning based on the four areas, zoning of A_a and A_v have been conducted in eight zones including:

1. Alborz with design acceleration of 0.35g;
2. Alborz with design acceleration of 0.30g;
3. Zagros with design acceleration of 0.35g;
4. Zagros with design acceleration of 0.30g;
5. Zagros with design acceleration of 0.25g;
6. Central Iran with design accelerationof 0.35g
7. Central Iran with design acceleration of 0.30g; and
8. Central Iran with design acceleration of 0.25g.

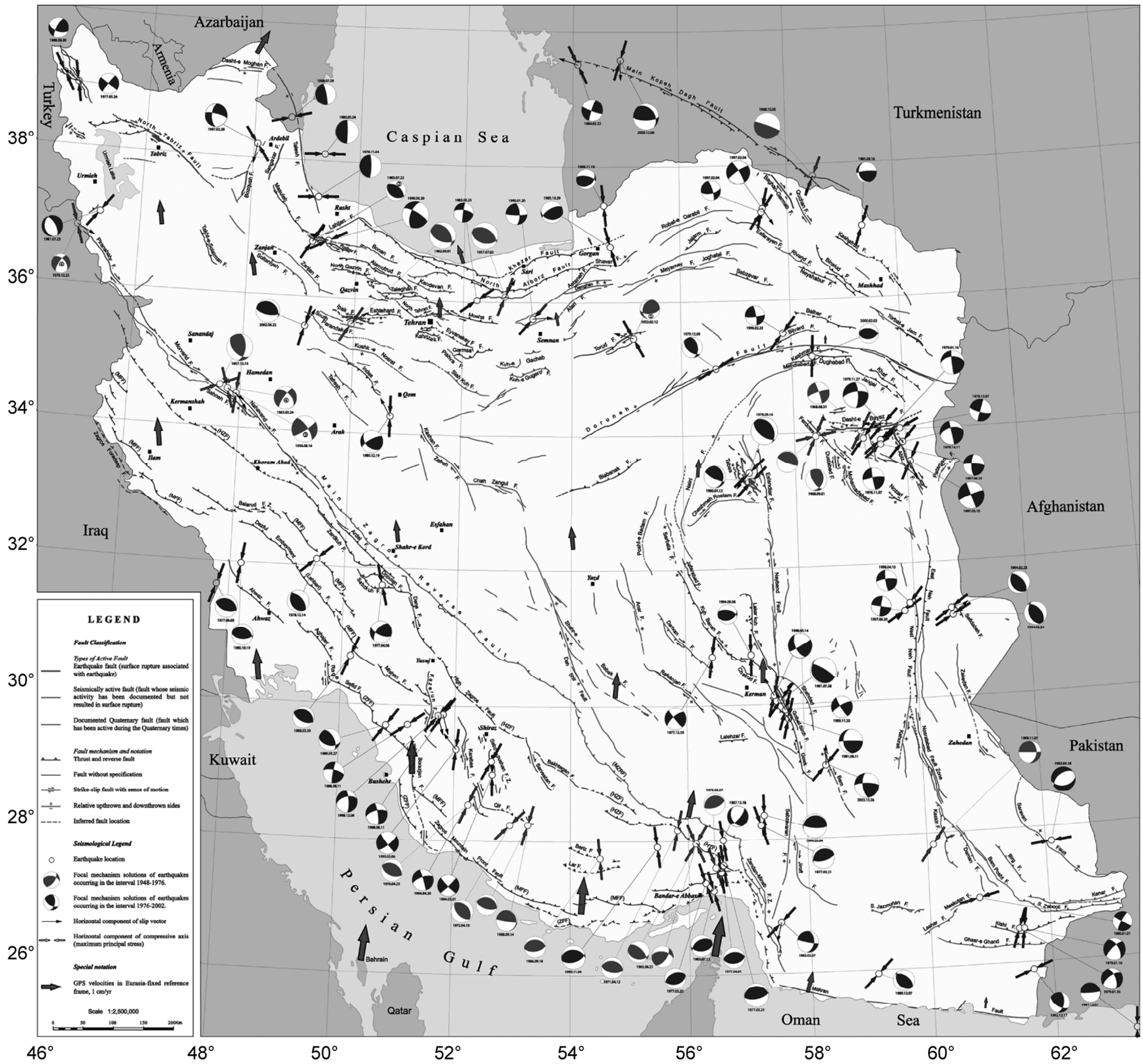

Figure 3. Major active faults of Iran [7].

The exact location of the epicenters has been specified in all provinces to normalize records using the BHRC website maps [8].

The other problem which must be observed is that the structure conditions are considered naturally in accelerometery; because for each point, the accelerometer of the same point or its surrounding is applied. In other words, it just compares the accelerations values without any change in frequency content and accelerometer's sustainment period.

Then applying the zoning map, see Figure (4) [8], and the seismic coefficient tables of the Manual 2800, we achieved the base acceleration values for each point of the design.

Finally, the coefficients achieved from Eq. (2) for each calculation point, were applied in each accelerometer to normalize data

$$\text{Revisory Coefficient} = \frac{\text{Design Acceleration}}{\text{Maximum Amount of Acceleration}} \quad (2)$$

The next step of specifying A_a and A_v coefficients is computing the acceleration and velocity spectra of all records (response spectra with one degree freedom for damping values of 5%). SeismoSignal software with reception of the record as an input file provides useful information about acceleration and velocity spectra. Calculating the response spectra, the data are transmitted to Excel program and the EPA and EPV are achieved based on the ATC (Applied Technology Council, 1978) suggested definitions. The Eq. (1) have been applied

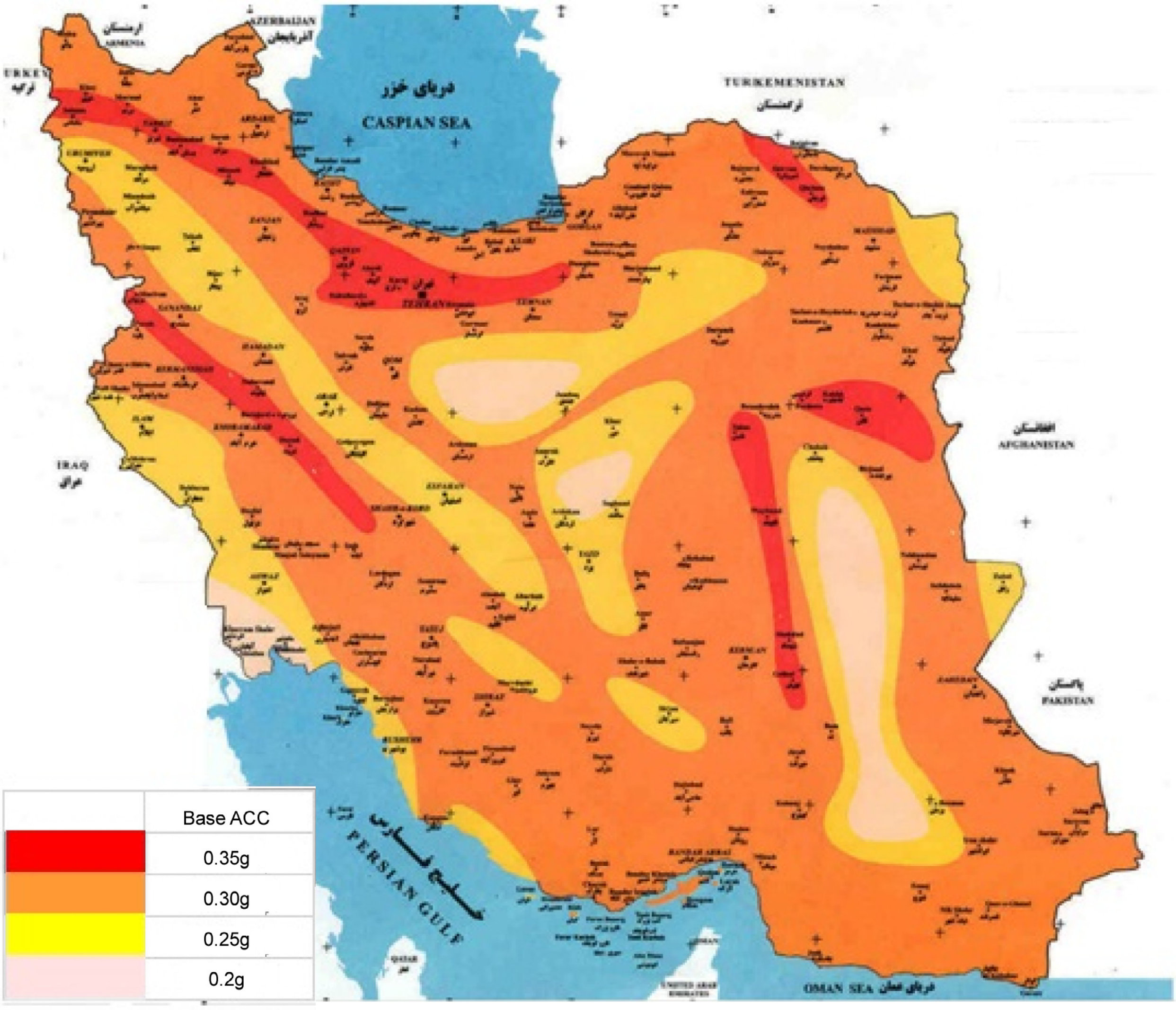

Figure 4. Seismic macrozonation hazard map of Iran [8].

in this regard where the EPA is a g coefficient and EPV is dimensioned in in/sec. Changing the value of calculated EPV in cm/sec; A_v would be evaluated as:

$$A_v = \frac{EPV}{30}(in/sec) = \frac{EPV}{30}(cm/sec) \times 0.3937 \qquad (3)$$

Table (1) represents the selected station information and the result of the calculated values of the A_a and A_v.

Comparison between the suggested filter values in this paper with those presented in other references in Iranian records, for example those recorded in 1993 to 2004 in reference No. 5 shows more or less the same result.

Whereas, there are just a few records in Alborz and Zagros with design acceleration of 0.35 g; some records from the same zones but with 0.30 g design acceleration were selected and normalized, to the base acceleration of 0.35 g. Figure (5) shows the suggested zoning results.

The k_h Eq. (1) is simplified as Eq. (4) where d is in cm.

$$k_h = G d^{-1/4} \qquad (4)$$

The values of "G" and the seismic coefficients (A_a and A_v) for selected Iran's seismic zones are shown in Table (2).

5. Determination of Allowable Displacements

The acceptable and maximum levels of the permanent ground displacements established based on the Owner's minimum performance expectation for the retaining wall should be revised. The tolerable seismically induced displacement depends on the

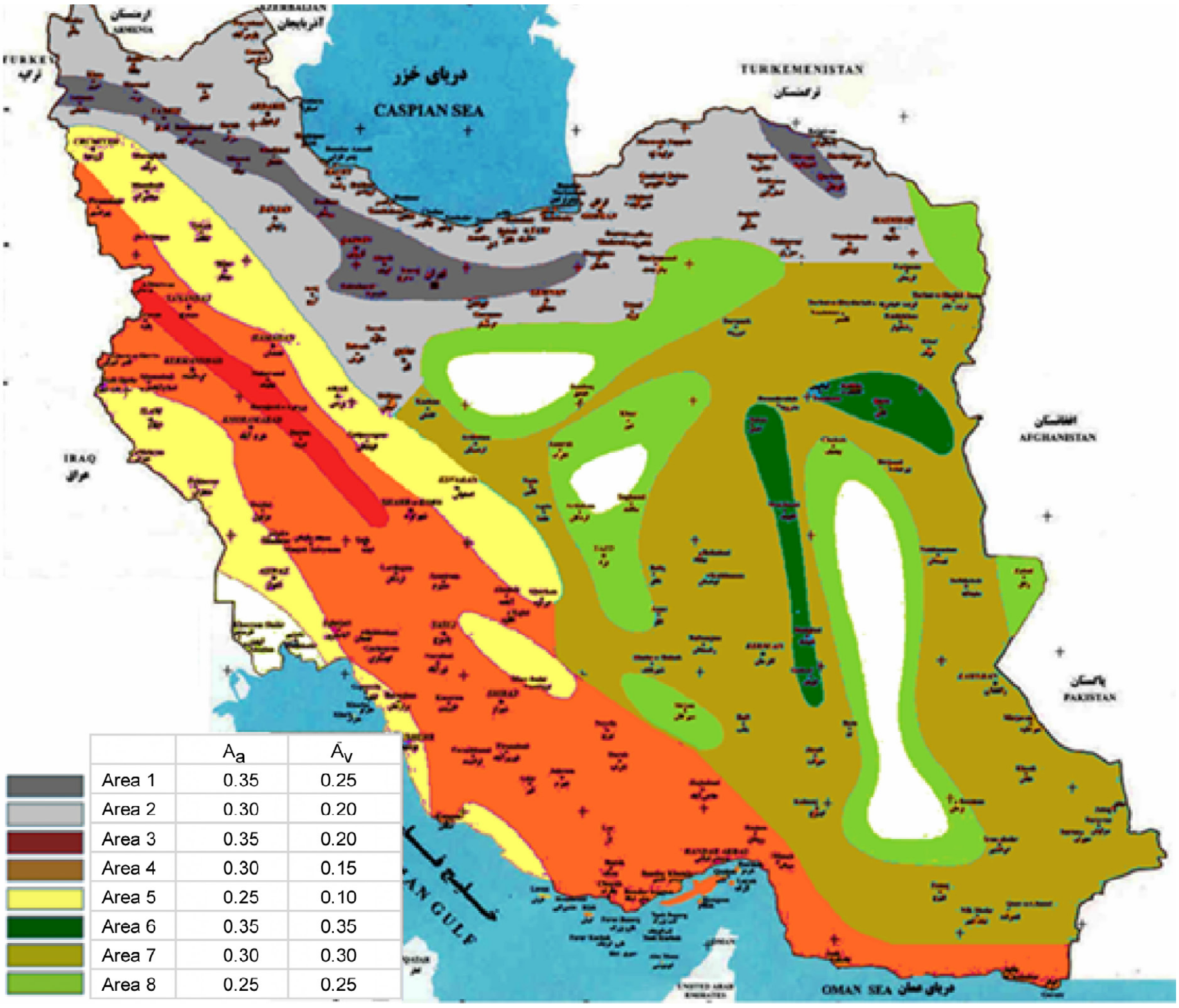

Figure 5. Zoning map of the seismic coefficient "G" suggested for Iran.

Table 2. Seismic coefficient values suggested for Iranian zones.

	Alborz	Alborz	Zagros	Zagros	Zagros	Central Plateau of Iran	Central Plateau of Iran	Central Plateau of Iran
Design Acceleration	0.35 g	0.30 g	0.35 g	0.30 g	0.25 g	0.35 g	0.30 g	0.25 g
Area	1	2	3	4	5	6	7	8
A_a	0.35	0.30	0.35	0.30	0.25	0.35	0.30	0.25
A_v	0.25	0.20	0.20	0.15	0.10	0.35	0.30	0.25
G	0.19	0.15	0.17	0.13	0.09	0.23	0.19	0.15

wall type and the serviceability of the wall provided. It should be noted that the Eq. (1) may not be used for displacements of less than 25 mm (1 inch) or greater than approximately 200 mm (8 inches). In general, typical practice among states located in seismically active areas is to design walls for reduced seismic pressure corresponding to 50 to 100 mm (2 to 4 inches) of displacement [9]. However, the amount of tolerable deformation depends on the nature of the wall and what it supports, as well as what is in front of the wall [10].

6. Conclusions

The aim of this research is to calculate the Richard and Elms' coefficients, so that the equation becomes applicable in Iran's seismic conditions. For this purpose, among the three-component records of the country's accelerometery network (BHRC) those with values higher than 5.5 (were selected $dn = 427$). They have been recorded in various stations from 1975/7/3 to 2007/1/12.

For all data, processing program was applied. The digital accelerometer processing was conducted using SeismoSignal V.3.2.0. Since other factors such as frequency content, the predominant period and P.G.A. are effective in calculation of A_a and A_v most effective and strongest records of each zone were selected as statistical data. Those records in focal distance of below 60 km and acceleration peak above 0.05 g (50 cm/sec^2) and with low limit frequency of (f_{HP} < 1.0) were screened from 427 records. Finally, 142 records were confirmed and selected; then amending baseline and filtering all accelerograms were conducted.

Zoning of code was conducted to the zonation map of A_a and A_v. After processing the accelerograms with regard to the zoning map, they were normalized to the area's acceleration coefficients, depending on different zones.

Using the seismic coefficients or the "G" value for Iran and selecting an appropriate allowable displacement, k_h can be determined by the Richard and Elms [3] formula.

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