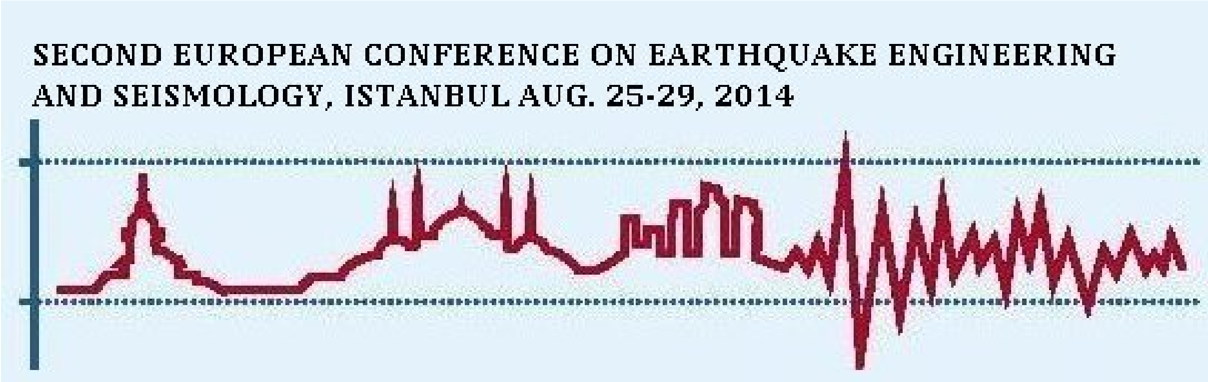

PROPOSITION OF FAR-FIELD SEISMIC RECORDS SUITABLE FOR 2-D NONLINEAR TIME-HISTORY ANALYSES IN IRAN

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ABSTRACT

Regarding the catastrophic aftermath of earthquakes, having a reliable approach to assess the seismic demands proper to the region of interest seems inevitable. The scope of this study is to provide a list of far-field seismic records applicable to 2-D nonlinear time history analyses in Iran. To do that a set of 2000 seismic records from Iran's seismic records database has been investigated based-on their characteristics, amongst are focal distance, magnitude, rupture mechanism, frequency content, and soil profile.

For the purpose of this study, at first, all the 2000 records have been categorized based on their focal distance and the records with Peak Ground Acceleration less than 0.1 on scale of g, and records with focal distance less than 5km have been omitted. In the second step, the remaining records have been set into categories based on their stations' soil profile. For the next step, the database from previous step is organized according to their rupture mechanism, and in last step, the records with the characteristics of near-fault ground motions are excluded. Finally an ensemble of 20 seismic records is selected from the aforementioned set that is suited for 2-D nonlinear time history analyses in Iran

INTRODUCTION

In current design procedure of structures, especially for those located in area with high level of seismicity, seismic design is inevitable. In seismic design of a structure, proper estimation of seismic demand is of great importance; therefore current codes have proposed procedures for that purpose. In majority of modern codes there are three methods for modeling seismic force; namely, equivalent static method, response spectrum method, and time history method. The first two methods are based on thorough procedures with specific regulations, yet the later is more sophisticated and relies fairly on proper understanding of seismology, in that it requires sets of ground motion accelerations conforming the criteria specified by the codes.

Regarding that Iran is a seismically active country, there is a need for a suite of records applicable to time history analyses, like those presented in FEMA-P695 (2008) for United States of America. The scope of this study is to propose this suit of records for Iran based on the regulation presented in Iranian Code of Practice For Seismic Resistant Design of Buildings Standard No.2800 (2005).

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STANDARD NO.2800 REGULATIONS FOR SELECTING SUITABLE RECORDS

According to this standard's regulations, acceleration records used in analysis of structures shall be carefully selected to properly reflect the strong ground motion of the site of interest; therefore the code suggests a suite of not less than three appropriate ground motions.

These records should conform the following requirements. They shall be obtained from actual events with magnitudes, fault distances, and source mechanism that are consistent with the code design spectra. The acceleration histories shall account for the regional tectonic settings, geology, seismicity, and site soil profile similar to condition of site of interest. And their duration times shall be greater than maximum of 10 seconds and three times the structure natural period.

In accordance with this standard's regulations, four types of soil profile are presented based on shear wave velocity; namely, Soil Type I with shear wave velocity values more than 750 m/s, Soil Type II with shear wave velocity values vary from 375 to 750 m/s, Type III with shear wave velocity values vary from 175 to 375 m/s, and Type IV with shear wave velocity less than 175 m/s,

THE PROPOSED PROCEDURE FOR SELECTING PROPER FAR-FIELD RECORDS FOR IRAN

In this study an ensemble of 20 records out of about 2000 corrected records from events that happened between 1978 and 2007 ,collected from Iran strong motion database, is proposed as shown in Table 1. The selection procedure is comprised of four steps which are discussed in following A, B, C , and D sections.

Table 1. List of Suggested Records

#	Event Name	Event Magnitude	Year	Station	Component[1]
1	Changureh	6.4	2002	Avaj	L
2	Changureh	6.4	2002	Avaj	T
3	Khuli-buniabad	7.1	1979	Qaen	L
4	Rudbar	7.3	1990	Ab-bar	L
5	Rudbar	7.3	1990	Ab-bar	T
6	Rudbar	7.3	1990	Qazvin	L
7	Zarand	6.3	2005	Zarand	L
8	Zarand	6.3	2005	Zarand	T
9	Zarand	6.3	2005	Qadrouni Dam	L
10	Zanjiran	5.8	1994	Meymand	L
11	Zanjiran	5.8	1994	Meymand	T
12	Zanjiran	5.8	1994	Firouz Abad	T
13	Silakhur	6.1	2006	Toshke abe sard	T
14	Tabas	7.4	1978	Deyhook	L
15	Tabas	7.4	1978	Deyhook	T
16	Tabas	7.4	1978	Tabas	L
17	Tabas	7.4	1978	Tabas	T
18	Fandoqa	6.6	1998	Sirch	L
19	Fandoqa	6.6	1998	Sirch	T
20	Kojour	6.2	2004	Poul	L

[1] T=Transverse, L=Longitudinal

A. CLASSIFICATION OF THE RECORDS BY THEIR EPICENTRAL DISTANCE

This is the first step of classification, in which acceleration histories are organized with respect to their epicentral distance. This way near-field records can be omitted from the database. All the 2000 collected records here belong to events with 6 to 98.2 km epicentral distances.

As it is stated in ASCE7 (2010), ground motion records with more than 3 miles (about 5 Km) distance from the epicenter are considered far field. However, there are different issues on this subject in technical literature. The best way to approach a good judgment about the ground motion records seems to be controlling the existence of near field components in each record. Thus, after the computation of epicentral distance for each record, those containing near field components are eliminated from the database.

Table 2. Epicentral Distance of records

#	Event Name	Station	Component[1]	Epicentral Distance
1	Changureh	Avaj	L	6
2	Changureh	Avaj	T	6
3	Khuli-buniabad	Qaen	L	52
4	Rudbar	Ab-bar	L	32.3
5	Rudbar	Ab-bar	T	32.3
6	Rudbar	Qazvin	L	98.2
7	Zarand	Zarand	L	16.2
8	Zarand	Zarand	T	16.2
9	Zarand	Qadrouni Dam	L	22.7
10	Zanjiran	Meymand	L	22.5
11	Zanjiran	Meymand	T	22.5
12	Zanjiran	Firouz Abad	T	27.8
13	Silakhur	Toshke abe sard	T	35.9
14	Tabas	Deyhook	L	18.7
15	Tabas	Deyhook	T	18.7
16	Tabas	Tabas	L	57
17	Tabas	Tabas	T	57
18	Fandoqa	Sirch	L	12.4
19	Fandoqa	Sirch	T	12.4
20	Kojour	Poul	L	11.5

B. CLASSIFICATION OF THE RECORDS BY THEIR STATION SOIL PROFILE

In the second step of classification, the records were organized according to their station soil profile type, based on the criteria specified by standard No.2800 regulations.

As it is mentioned earlier in this document, soil profile type categories in Standard No.2800 are based on average shear wave velocity in the top 30 meters of the soil profile; therefore for the purpose of this step, for each station the average shear wave velocity was obtained from a report by Sinaeian et al (2008) and United States Geological Survey databases. Also, As it is shown in Fig.1 noticeable portion of Iran could be set into soil type II category of Standard No.2800; thus, majority of selected records belong to station with soil profile type II. In Table 3 the list of selected records and their station soil profile types are presented.

Table 3. Soil Profile Types and Shear wave velocity

Event Name	Station	Component	Vs m/s	Soil Profile Type
Changureh	Avaj	L	1111	1
Changureh	Avaj	T	1111	1
Khuli-buniabad	Qaen	L	360-490	2
Rudbar	Ab-bar	L	360-490	2
Rudbar	Ab-bar	T	360-490	2
Rudbar	Qazvin	L	360-490	2
Zarand	Zarand	L	271	3
Zarand	Zarand	T	271	3
Zarand	Qadrouni Dam	L	300-490	2&3
Zanjiran	Meymand	L	360-490	2
Zanjiran	Meymand	T	360-760	2
Zanjiran	Firouz Abad	T	360-760	2
Silakhur	Toshke abe sard	T	360-490	2
Tabas	Deyhook	L	300-490	2&3
Tabas	Deyhook	T	300-490	2&3
Tabas	Tabas	L	360-490	2&3
Tabas	Tabas	T	360-490	2&3
Fandoqa	Sirch	L	689	2
Fandoqa	Sirch	T	689	2
Kojour	Poul	L	180-360	3

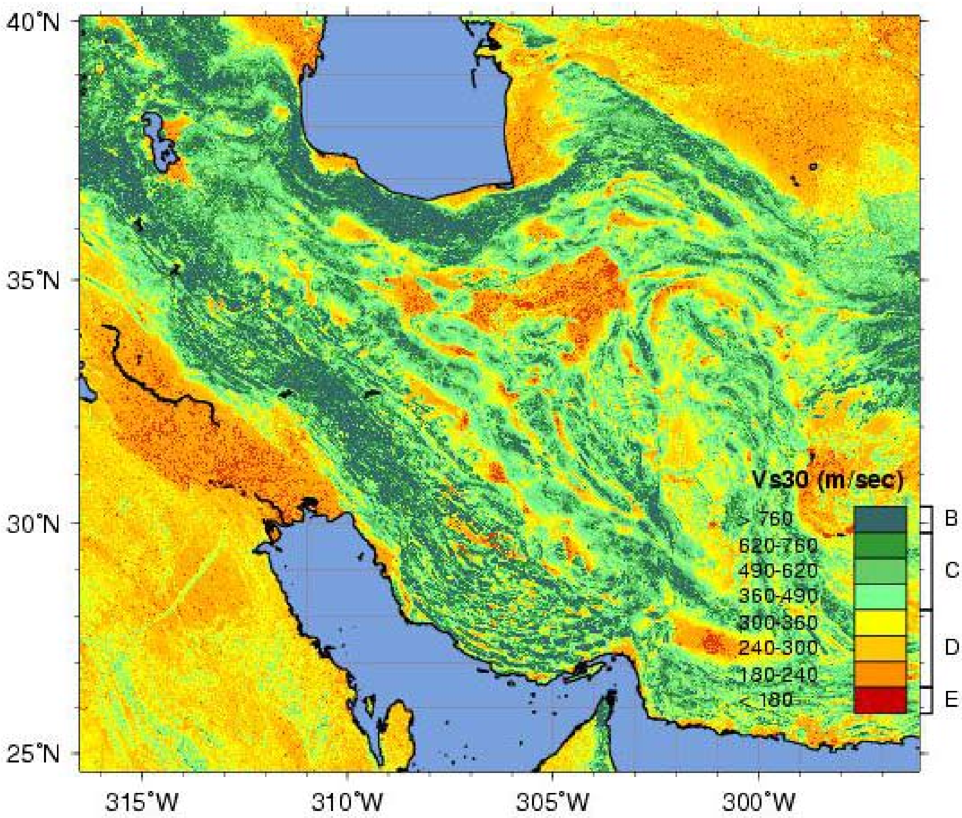

Figure 1. Acceleration Predefined Vs30 Mapping-USGS

C. CLASSIFICATION OF RECORDS BY THEIR FAULT MECHANISM

In this step the remaining records were categorized according to their fault mechanism. The fault rupture mechanisms were obtained from "Global Centroid-Moment-Tensor Project" (2013) database which is funded by United States National Science Foundation. For instance, Zanjiran event with a magnitude of 5.8 which took place in 1994 has strike-slip mechanism, Changure event with 6.4 magnitude that happened in 2002 has reverse-fault mechanism, the event of 1979 Khuli- Buniabad with 7.1 magnitude has strike-slip and tensile mechanism, and 2006 event of Silakhor with a magnitude of 6.1 has a strike-slip rupture mechanism. In Fig.2 to Fig.5 the beachball plots of aforementioned events are presented.

Further studies on this aspect through microzonation report of Tehran and Iran provided by Japan International Cooperation Agency (JICA) (2000) and Ashtari (2010) have revealed that most of the active faults considered in this study have reverse or strike-slip mechanism. Therefore, significant portion of the selected records have either reverse or strike-slip mechanism as shown in Table-4.

Figure 2. Beachball diagram for Zanjiran event

Figure 3. Beachball diagram for Changure event

Figure 4. Beachball diagram for Khuli-Buniabad event

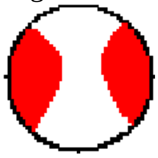

Figure 5. Beachball diagram for Silakhor event

Table 4. List of Suggested Records

Event Name	Station	Component[1]	PGA [1] (g)	PGV [1] (cm/s)	Mechanism
Changureh	Avaj	L	0.494	23.6	Reverse
Changureh	Avaj	T	0.465	19.3	Reverse
Khuli-buniabad	Qaen	L	0.215	11	Strike-Slip and Tensile
Rudbar	Ab-bar	L	0.597	54.4	Tensile
Rudbar	Ab-bar	T	0.54	57.9	Tensile
Rudbar	Qazvin	L	0.206	29	Tensile
Zarand	Zarand	L	0.326	26.3	Reverse
Zarand	Zarand	T	0.241	22.1	Reverse
Zarand	Qadrouni Dam	L	0.223	15.5	Reverse
Zanjiran	Meymand	L	0.448	18.4	Strike-Slip and Reverse
Zanjiran	Meymand	T	0.502	18.9	Strike-Slip and Reverse
Zanjiran	Firouz Abad	T	0.289	9.2	Strike-Slip and Reverse
Silakhur	Toshke abe sard	T	0.382	8.6	Strike-Slip and Reverse
Tabas	Deyhook	L	0.325	20.3	Reverse
Tabas	Deyhook	T	0.4	27	Reverse
Tabas	Tabas	L	0.863	118.4	Reverse
Tabas	Tabas	T	0.849	92.3	Reverse
Fandoqa	Sirch	L	0.684	36.6	Strike-Slip and Tensile
Fandoqa	Sirch	T	0.481	91.85	Strike-Slip and Tensile
Kojour	Poul	L	0.296	10.8	Reverse

[1] PGA = peak ground acceleration, PGV = peak ground velocity

D.CLASSIFICATION OF THE RECORDS BASED-ON THEIR STRONG MOTION DURATION

In this step of the classification the remaining records are classified with respect to their strong motion duration. For that purpose, the Arias intensity plot of records, which is the total energy per unit weight stored by a set of undamped simple oscillators at the end of an earthquake (Tselentis 2011), have been investigated using the %5 and %95 thresholds, and considering the Standard No.2800 regulations, records with duration less than 10 seconds were removed. In Table 5 selected records with their duration time is displayed.

Table 5. Duration Time

Event Name	Station	Component[1]	Duration Time (Sec)
Changureh	Avaj	L	12
Changureh	Avaj	T	12
Khuli-buniabad	Qaen	L	18
Rudbar	Ab-bar	L	38
Rudbar	Ab-bar	T	38
Rudbar	Qazvin	L	40
Zarand	Zarand	L	35
Zarand	Zarand	T	32
Zarand	Qadrouni Dam	L	25
Zanjiran	Meymand	L	11
Zanjiran	Meymand	T	11
Zanjiran	Firouz Abad	T	15
Silakhur	Toshke abe sard	T	11
Tabas	Deyhook	L	39
Tabas	Deyhook	T	39
Tabas	Tabas	L	25
Tabas	Tabas	T	25
Fandoqa	Sirch	L	11
Fandoqa	Sirch	T	11
Kojour	Poul	L	25

CONCLUSIONS

Considering the complicated nature of time history analysis, which is an expensive and time consuming procedure, and the fact that the credibility of this analysis results is partly relied upon proper input, which here is referred to as acceleration histories, in the present study, a suite of acceleration history comprise of 20 far-field records from the actual events happed in Iran between 1979 to 2006 with magnitude of 5.8 to 7.4 applicable to 2-D time history analyses is presented.

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