INVESTIGATING THE ADEQUACY OF IRANIAN SEISMIC FOR DESIGN OF STEEL STRUCTURES NEAR- FAULT AREA
CASE STUDY: AHAR AND VARZEGHAN CITIES OF EAST AZARBAIJAN

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ABSTRACT

The recent studies have shown that there are differences between near-fault and far-fault earthquakes. Considering that, the seismic design code of Iran has not provided specific rules and regulations for designing structures in near-fault area sand with regard to the geological studies and the distribution of faults throughout Iran, in a way that many faults are given the name of their cities surrounded them including, Ahar fault, Tabriz fault and …, it seems necessary to consider the design of structures in near-fault areas. In this research, by study in the seismic regions and major earthquakes that have occurred in the given area, as well as, getting necessary information about the near-fault area and choosing the proper attenuation relation**,** it was attempted to calculate the Peak Ground Acceleration (PGA) using both deterministic and probabilistic methods. And then by calculating the base shear coefficient of three types a flow- rise, mid-rise and high-rise structures with special and intermediate steel moment frame systems in the study, it was considered that according to standard No. 2800 and the rules of UBC97regulationfor near-fault areas on various types of soils and their comparison in all cases, the values of the base shear coefficient near-fault were greater than those obtained from standard No. 2800. This issue can indicate that the near-fault structures designed based on standard No. 2800 do not have enough resistance and need to be improved. In order to verify the above three structural types of low-rise, mid-rise and high-rise, they were designed once using the 2800 code, and again by coefficient near-fault. And then all three types of structures using design spectra of 2800 and the special spectra of the site in near-fault area were performed by pushover analysis and the results of both near-fault and far-fault were compared. The results of the study obtained from the area near the site of Ahar and Varzeghan shows that the current criterion of standard No.2800 cannot meet the seismic requirement of structures in the near-fault areas.

INTRODUCTION

The structuredesigncodes have beenconstantlychanging and editing until nowwhich have been changed as the time passed and experience gained. But gaining the experience should not lead toloss of the human life.Geologicalstudiesindicate thatmanyIranian citiesare builtnear or onactivefaults.Itisobvious thatfaults areoneofthe major factorsthat willcausean earthquake.Near-faultearthquakeshave done great damagetostructures. However, dueto differences incharacteristicsofnear-fault earthquakewithfar-faultearthquakeand regardingthat no criterionis issuedfor designingthestructures innear-faultareain Iranian seismic designcode, it is clearthatthese rules andregulationsshould lead to reducethedamagetostructures, the adverse economic and socialeffectandmore importantly,safeguardingthehuman life during an earthquake,and moreoverconsiderthenear-faultrecordsand itseffecton improving the capacity andthe behavior of structure sagainst earthquakes.The purpose of this study is to find out whetherthe designed structures based on standard No. 2800 can provide the safety of life as expected in this standard.

HAZARD ANALYSIS

For designing earthquake-resistance structures, the recognition of strong ground motion that is expected to occur during the functional working life of structures has significant importance. The purpose of risk analysis is to define the probability of an earthquake with a specific intensity which may occur during a specific time.

DETERMINISTIC RISK ANALYSIS

The impossibility to input the functional working life of structures and conservative response from the output may be the weakest points of this method compared to probabilistic method. In general there are four primary steps for deterministic seismic hazard analysis as follows:
1- Identification of seismic sources in the range of 30 km around the site.
2- Calculating the greatest earthquake that may occur on each of the seismic sources.
3- Choosing the attenuation relations of the strong ground motion.
4- Calculating the maximum values of ground motion in relation to each of the sources. (To increase the accuracy of calculations on the greatest earthquake that may occur on each of the seismic sources, two methods of “magnitude- fault length relations” and also “Kijko” software is used in this research.

DETERMINING THE MAXIMUM MAGNITUDE OF THE SEISMIC SOURCE USING EMPIRICAL MAGNITUDE–FAULT LENGTH RELATIONS

Among the “magnitude– fault length relations” that has been presented by different researchers, the empirical relationship (Zare, Noroozi and Mohajer Ashjaei, Wells and Coppersmith, Ambraseys and Akasheh) has been used about each of the seismic source and the mean of these relationship considered as the maximum magnitude of that seismic sources at the end. The calculations for the study area are presented in table 1.

Table 1: Calculation of the maximum magnitude for Ahar-Varzeghan faults (radius 30 Km)

row	Fault name	fault **length (km)**	**Distance from resource (km)**	**Used relation ships**	**M_w**	**M_s**	**$M_{s(ave)}$**
1	Ahar fault	51	5.8	zaree	6.3	6.3	6.6
				Norozi, mohajer ashjaee		6.8	
				Velz, koper esmit	7.1	7.1	
				akashe		6.1	
				Ambraseys		6.6	

CALCULATION OF THE MAXIMUM MAGNITUDE OF SEISMIC SOURCES USING “KIJKO” SOFTWARE

For this purpose, with regard to the seismicity of region ,distribution of earthquakes and other parameters of seismology in the given area, the maximum magnitude can be calculated by providing a historical and instrumental earthquake catalog relating to each fault in that zone. The maximum magnitude in the given area of major seismic zone is presented in table 2.

Table 2 : Determining the maximum magnitude in Varzeghan and Ahar faults (radius 30 km)

Fault name	Ahar fault
M_{max} (Kijko)	7.9

CHARACTERISTIC MAGNITUDE

In the previous section two maximum magnitudes obtained from "magnitude- fault length relations" and using "Kijko" software. Now considering the observed magnitude for each fault, the mean value is calculated for fault as a characteristic magnitude.

Table 3: Characteristic magnitude for Ahar – Varzeghan faults

Fault name	***M*** بزرگا-طول گسل	M_{kijko}	$M_{obseruational}$	M_{ave}
Ahar fault	6.6	7.9	6.2	6.9

DESCRIPTION OF ATTENUATION MODELS

An attenuation relation states the relation between the strong ground motion parameters with at magnitude distance for a specific earthquake and the condition of geology.

ENGINEERING JUDGMENT AND LOGICAL TREE

By using logical tree method different models can be used by weight given to each model (that is, relative probability of the accuracy of each model). Logical tree shows different branches on each node that is related to different models.

In deterministic method, the maximum horizontal acceleration at site is related to a fault that causes the most horizontal acceleration at the given site. In the table below the maximum horizontal acceleration of different attenuation relationship and their weighted mean relating to Ahar fault is determined.

Table 4: The maximum horizontal acceleration at the site

Fault name	Soil type	روابط کاهندگی			Weight average
		Boore	Campbell	Ambraseyes	
Ahar fault	I	0.522	0.599	0.735	0.619
	II	0.556	0.601	0.962	0.706
	III	0.607	0.571	0.978	0.719
	IV	0.445	0.448	0.978	0.624

PROBABILISTIC RISK ANALYSIS

Like deterministic, probabilistic risk analysis can be described in four steps:

- Identification of seismic sources and seismic survey area.
- Seismicity or time distribution of seismic events.
- Choosing the proper attenuation relationship.
- Estimation of strong ground motion parameters for design.

USING EZ-FRISK SOFTWARE

To do the probabilistic analysis, EZ-Frisk software has been used in this research. The result is shown in table 5.

Table 5: The PGAH value of Ahar-Varzeghan site

Soil type	Level risk	
	DBE	MCE
I	0.443	0.744
II	0.512	0.888
III	0.534	0.913
IV	0.552	0.901

Calculation of base shear coefficient in the study area based on standard No. 2800 and the rules of the UBC97 regulations

UBC97 regulation is one of the most widely adopted models building codes for design load and building structures. In order to compare the near-fault area base shear coefficient with base shear coefficient in standard No, 2800, it is decided to calculate the base shear coefficient based on both methods for structures with different lateral resisting systems at the given site. The results of the calculations are presented in table 6.

Table 6: Summary of results in base shear coefficient

Soil type	**Structure height (m)**	Resistant system	T_0	T_s	T	B	R_{2800}	R_{NF}	C_{2800}	C_{NF}
I	9.6	special	0.1	0.4	0.273	2.5	9	5.77	0.0972	0.162
		mediocre	0.1	0.4	0.273	2.5	7	5.05	0.125	0.185
	22.4	special	0.1	0.4	0.515	2.113	9	12.6	0.0822	0.1871
		mediocre	0.1	0.4	0.515	2.113	7	9.8	0.1056	0.241
	35.2	special	0.1	0.4	0.723	1.685	9	12.6	0.0655	0.1871
		mediocre	0.1	0.4	0.723	1.685	7	9.8	0.0843	0.241
II	9.6	special	0.1	0.5	0.273	2.5	9	5.77	0.0972	0.155
		mediocre	0.1	0.5	0.273	2.5	7	5.05	0.125	0.1278
	22.4	special	0.1	0.5	0.515	2.452	9	12.6	0.0954	0.2076
		mediocre	0.1	0.5	0.515	2.452	7	9.8	0.1226	0.2669
	35.2	special	0.1	0.5	0.723	1.956	9	12.6	0.0761	0.2076
		mediocre	0.1	0.5	0.723	1.956	7	9.8	0.0978	0.2689
III	9.6	special	0.15	0.7	0.273	2.75	9	5.77	0.1069	0.1083
		mediocre	0.15	0.7	0.273	2.75	7	5.05	0.1375	0.1929
	22.4	special	0.15	0.7	0.515	2.75	9	5.77	0.1069	0.1083
		mediocre	0.15	0.7	0.515	2.75	7	5.05	0.1375	0.1929
	35.2	special	0.15	0.7	0.723	2.692	9	12.6	0.1047	0.2160
		mediocre	0.15	0.7	0.723	2.692	7	9.8	0.1346	0.2777
IV	9.6	special	0.15	1	0.273	2.75	9	5.77	0.1069	0.4951
		mediocre	0.15	1	0.273	2.75	7	5.05	0.1375	0.5657
	22.4	special	0.15	1	0.515	2.75	9	5.77	0.1069	0.4951
		mediocre	0.15	1	0.515	2.75	7	5.05	0.1375	0.5657
	35.2	special	0.15	1	0.723	2.75	9	5.77	0.1069	0.4951
		mediocre	0.15	1	0.723	2.75	7	5.05	0.1375	0.5657

It is observed that in all cases the value of C_{NF} (near-fault area base shear coefficient) is greater than C_{2800} (base shear coefficient based on standard N0. 2800). The results of calculation based on proposed method for near-fault area base shear coefficient shows that the values of near-fault area base shear coefficient is greater than the base shear coefficient obtained from standard No. 2800 in all cases. This can express that the structures which were designed near-fault based on standard No. 2800, has not sufficient resistance. Hence the structures which are in near-fault area, particularly the structures that are less than 5 km from active fault, should be evaluated again and improved when necessary.

CONTROLLING THE ACCURACY OF BASE SHEAR AT NEAR-FAULT AREA

In order to verify the accuracy of base shear coefficient in near-fault area three types of low, mid and high-rise structures were chosen. These structures were designed using shear base coefficient and again by near-fault coefficient. Afterwards, in order to compare the performance-based seismic design of structures with the criterion of three types of structures using 2800 spectra and the specific spectra of the site ,pushover analysis was performed and the results of two areas of near-fault and far-fault were compared .

CHOOSING AND PREPARING MODELS

In this paper three models of steel moment frames with brace are used that have 7 stories (low-rise building), 11stories (mid-rise building) and 21stories (high-rise building) respectively. The location of the belt truss in 7stories, 11 stories and 21 stories structure has been considered in 1/2 height, one-third and tow-third of the structure respectively. These models are three-dimensional and consist of 5 frames in each direction. All the spans are 5m and each story has 3m height in the steel frame.

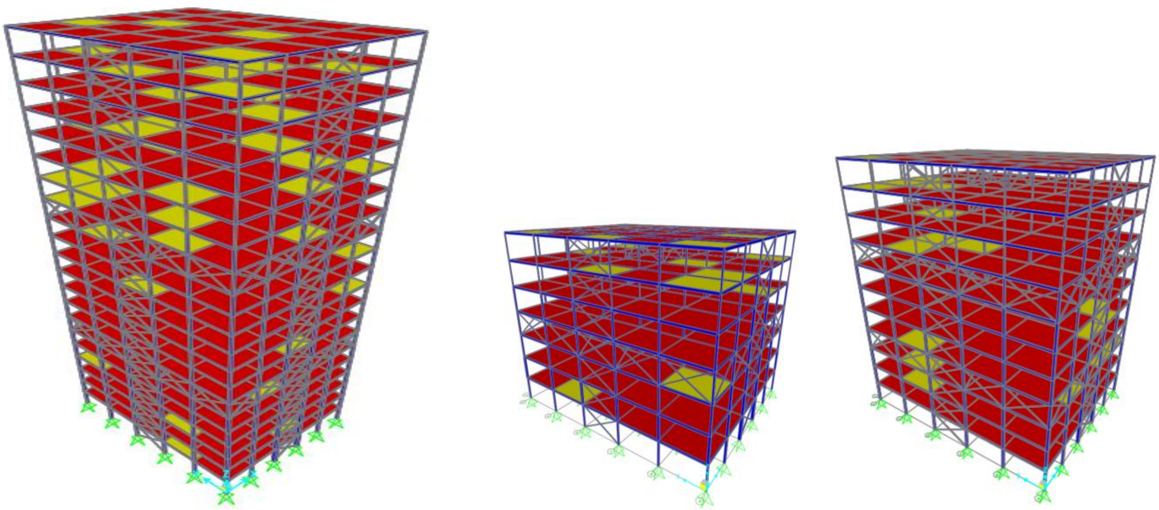


Figure 1: 7-story, 11-story, and 21-story three-dimensional Building structures

In all models the built-up box section used in intersection of columns and braces and I-shaped profile (IPE profiles) used in intersection of beams. It should be noted that compact sections were chosen. Rigid floor assumption was used in all analysis of models. Iranian National Building Regulation part 6 has been used for loads of dead load and live load. Thus, the values obtained from roof and floor dead loads were equal to 500kg/m2 and floor live load 200kg/m2 and roof live dead 150kg/m2. Standard No. 2800also was applied to earthquake loads. For this purpose, it is assumed that all models are intermediate moment frame system with the truss bracing. The given models have been considered in both near–fault and far-fault area in Ahar and Varzeghan (Iran). First the given structures were designed and after completing all designed phases, all sections of beam, column, and brace should meet the needs of the structures. By performing pushover analysis, the performance of the structures in both near–fault and far-fault area will be reviewed. Once again, the aforementioned structures were designed using criterion of near-fault seismic design code and then performed by pushover analysis.

PREPARING MODELS FOR NONLINEAR STATIC ANALYSIS

The initial modeling of three structures was designed according to mentioned seismic design criteria. In this part, two-dimensional models for nonlinear static analysis using software sap2000 were carried out. The reason of two-dimensional model for analysis, regardless of possible torsion in structures, was the symmetry and the regularity of three structures in two orthogonal directions.

THE RESULTS OF THE STUDY

Near-fault area base shear coefficient in all structures and different types of soil is greater than proposed base shear coefficient based on standard No. 2800 and this shows the inadequacy of standard No.2800 in near-fault area. In below figures, the base shear coefficient based on standard No.2800 and near-fault area is compared with UBC97 regulation in a 3, 7 and 11-story structure in different types of soil.

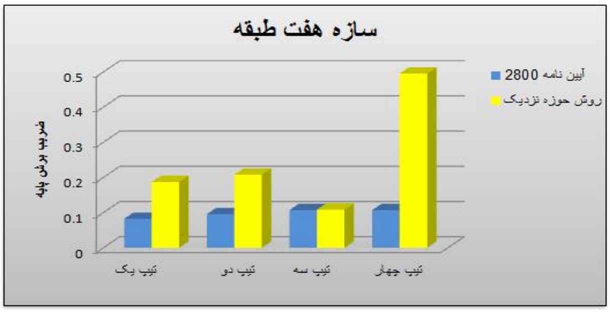
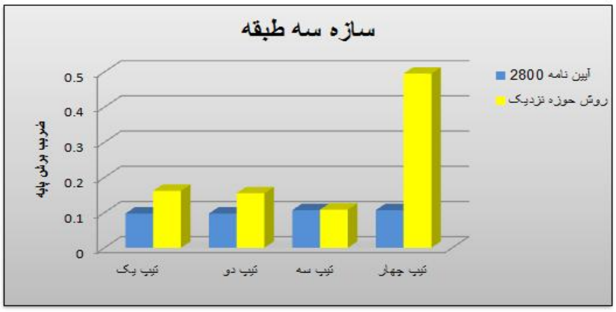


Chart1: Comparison of near-fault area base shear coefficient and standard No.2800 in a 7-story



Chaet2: Comparison of near-fault area base shear coefficient and standard No.2800 in a 3-story

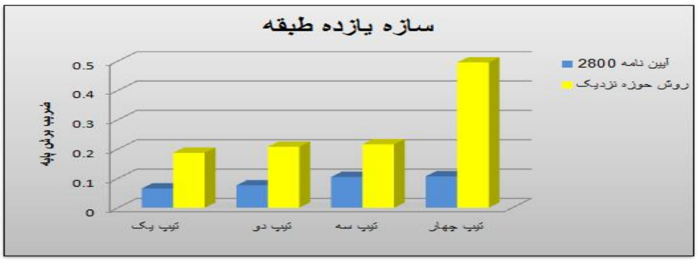


Chart3: Comparison of near-fault area base shear coefficient and standard No. 2800 ina11-story structure

THE RESULTS OF PUSHOVER ANALYSIS

The seismic performance of the structures in two areas of near-fault and far-fault is considered in this part. As it is shown in these figures, the 7-story structure designed according to standard No. 2800 and even in pushover analysis using spectra with those in standard No. 2800 violates the expected performance of the standard. This expresses the fact these designs cannot provide the expected level of performance. However, the structures which are designed based on near-fault rules could obtain the expected level of performance.

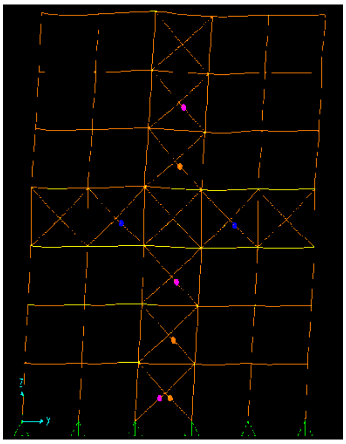


Figure 2: Structural design based. on standard No. 2800 and pushover analysis by site specific spectra.

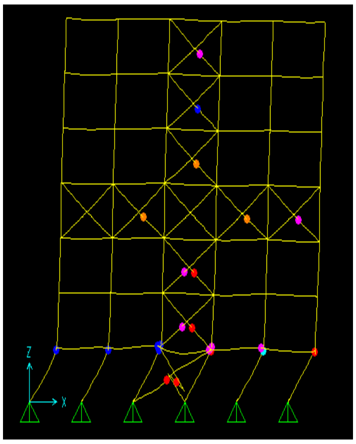


Figure 3: Structural design based on standard No. 2800 and pushover analysis by spectra 2800

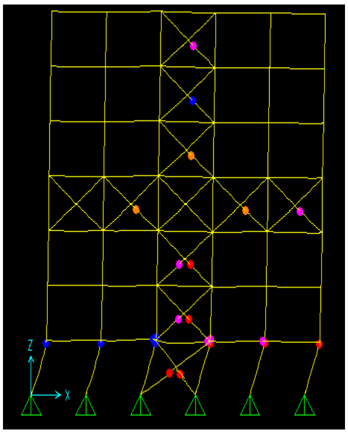


Figure4: Structural design based on near-fault area and pushover analysis by site specific spectra

In a 11-story structure which is designed based on standard No. 2800 in both near-fault and far-fault area, the life safety has been violated, however in the structures designed based on developmental regulation, the level of life safety is provided.

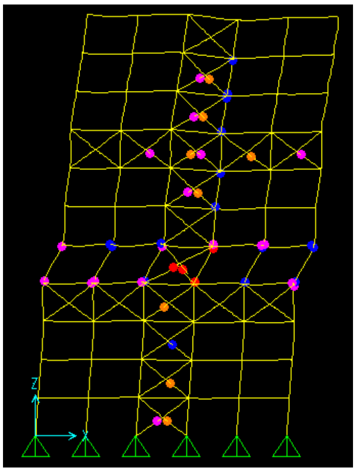


Figure 5: Structural design based on standard No.2800 and pushover analysis by site specific spectra

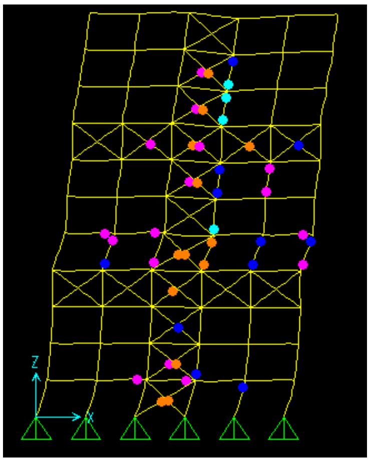


Figure 6: Structural design based on standard No.2800 and pushover by analysis by spectra 2800

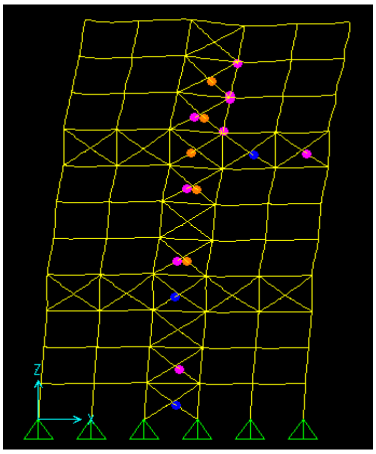


Figure7: Structural design based on near-fault area and pushover analysis by site specific spectra

In a 21-story structure designed based on standard No. 2800 in far-fault area, the structure could provide the expected level of life safety however, the level of performance in near-fault area is violated. The structures designed based on near-fault criteria could provide the expected performance criteria. It can be assumed that standard No. 2800 acted conservatively in long period about high rise structures, thus seismic performance of such structures is better than low and medium rise structures in near-fault area.

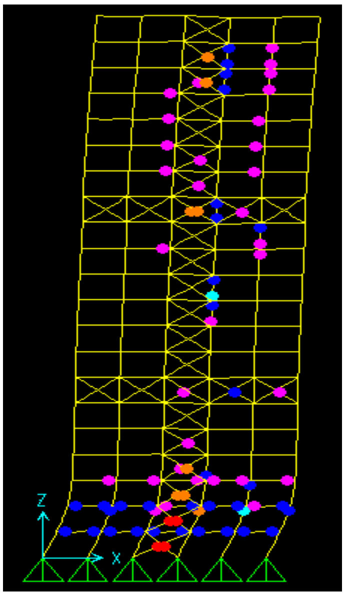


Figure8: Structural design based on standard No.2800 and pushover analysis by site specific spectra.

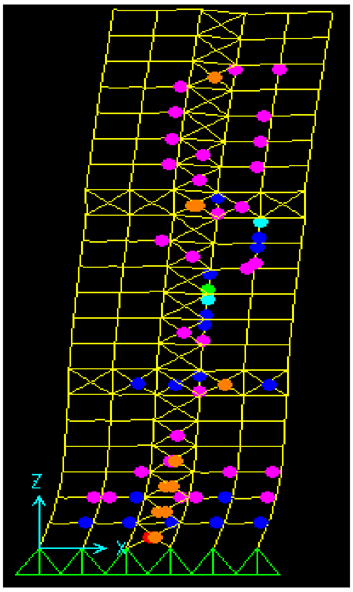


Figure9: Structural design based on standard No .2800 and pushover analysis by spectra 2800

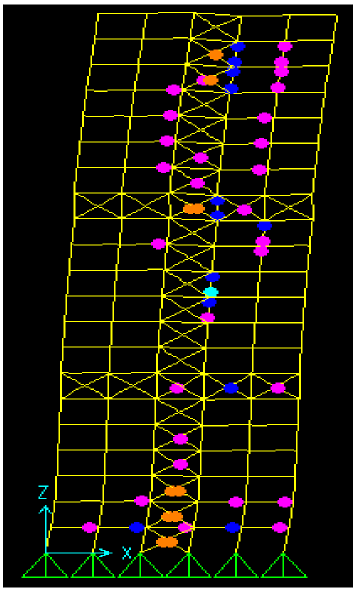


Figure10: Structural design based on near-fault area and pushover analysis by site specific spectra.

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