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Introducing a New Approach for Modelling the Near Field Effects in Probabilistic Seismic Hazard Analysis

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ABSTRACT: In definitions of seismic hazard analysis, if the site distance from the fault causing earthquake is short, that site will be considered near fault. The recorded results of previous earthquakes have shown that in such site, the structures show very complex and different behaviour from far field area such that it is required to consider near fault seriously and independently. So far, various studies have been carried out to present a method for reliable modelling of near fault behaviour including the present study. In fact, so far, no reliable and definite method has been proposed for modelling of near field effects in probabilistic seismic hazard analysis and this study aims to take some steps in this area. The present study proposes a new solution based on combined use of both spectral attenuation relations, i.e. spectral attenuation relations with near field effect and spectral attenuation relations lacking near field effects, for calculation of probabilistic seismic hazard analysis. The results of this study indicate the capability of this new idea in modelling of near field effects for reliable estimation of seismic hazard. The results of this study show that the use of attenuation relations of near field, individually, for seismic hazard analysis, increases the spectral acceleration tangibly and unacceptably and is not much reliable. Thus, to overcome this deficiency, one can claim that the best solution for consideration of near field effects is to use the combination of both near and far field attenuation relations according to the proposed model in this study.

Keywords: Earthquake, Fault, Near Fault, Probabilistic Seismic Hazard Analysis, Attenuation Relations

INTRODUCTION

Earthquake is indicative of continuous movement of the earth's crust and considered as one of the most destructive natural phenomenon that adversely affects many people all over the world. Iran is a country where numerous devastating earthquakes have occurred to date with irreparable losses and damages. Iran's plateau being located in Alpine- Himalaya orogeny belt, which is one of the most seismically active areas of the world, and other geological, seismic, seismology and geophysics evidences indicate that there is always the possibility of another major earthquake in Iran territory. It seems that in the current situation and by current knowledge of human being, the only way to confront this natural phenomenon is to design the structures resistant against earthquake and retrofitting the current structures against earth movement due to earthquake. In other words, it is possible to achieve a desired safety against seismic hazard through design of new resistive structures and seismic rehabilitation of existing structures and thus to minimize the human and financial losses. To this end, i.e. to reduce the susceptibility of structure against earthquake, it is required to select a proper method for analysis and design of structures against the induced forces against earthquake and to have logical and reliable estimation of earthquake forces. Such requirements enable the designer to desirably perform the designing of resistive structures against earthquake or perform seismic rehabilitation of an existing structure. However, this reliable and logical estimation of forces due to earthquake is considered a challenge because of uncertainties in earthquake. Earthquake is an accidental phenomenon with uncertainties in its location, time, magnitude, wave propagation and its resulting effects, which made estimation of forces due to earthquake a complicated task. To overcome this difficulty, many studies have been carried out which on overall lead to development of a new method entitled, probabilistic seismic hazard analysis. The aim of probabilistic seismic hazard analysis in a site is to evaluate logically the parameters of earth movement in the intended site due to earthquake occurrence in potentially seismic sources in certain time (kramer, 1996). This method, which is the most recent introduced method in seismic hazard analysis, has been obtained through combination of probability concepts and seismic geotechnical issues. It is possible to consider the uncertainties in various parameters through this method and apply the variations in location and magnitude of earthquake in calculations, properly. Probabilistic seismic hazard analysis provides the ground for identification of the uncertainties and their quantitative application in seismic hazard. Although, current probabilistic seismic hazard analysis is a practical method for estimation of forces due to earthquake, one should consider that this method faces new challenges in some cases including seismic hazard analysis in near fault. In definitions of seismic hazard analysis, if the site distance from the fault-causing earthquake is short, the mentioned

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site is considered near fault. The results of previous earthquakes have shown that in this site, structures show very complex and different behaviour than far fault such that it is required to study near fault independently and seriously. So far, many studies have been carried out with the aim of proposing a method for reliable modelling of near fault behaviour. The above discussion can be used for defining the aim of this study. Generally, this study is included in probabilistic seismic hazard analysis category, however, it follows certain specialized objective which is proposing a new solution for modelling of near field effects in probabilistic seismic hazard analysis. In other words, in this study, the researchers tried to add a new component to general method of probabilistic seismic hazard analysis to make it reliably efficient for estimation of forces due to near fault earthquakes. This new idea, which has originated from conditional combination of far fault and near fault attenuation relations, can be very significant in seismic hazard analysis in seismic zones with near fault specifications. In the next parts of this paper, after a brief introduction of probabilistic seismic hazard analysis, the role of attenuation relation in this analysis and the challenges of near fault will be explained. Then, after proposing the main research plan, which is in fact seismic hazard analysis in the target territory of Tehran, the selection of proper attenuation relations will be done and the main idea of this paper in their conditional combination will be introduced. Then the results of using this idea in probabilistic seismic hazard analysis will be presented to determine its effectiveness in modelling of near field effects. The discussion of advantages and disadvantages of this new ideal will be the final part of this paper.

MATERIAL AND METHODS

Probabilistic seismic hazard analysis

The complexity of natural phenomenon, generally, and a phenomenon such as earthquake, specifically, made it almost impossible to control such phenomenon by present knowledge and to determine precisely the location and magnitude of future earthquakes. In such cases, use of probability and statistics is probably the only possible and practical option in analysis of such phenomenon. The combination of the concepts of probabilistic statistics and seismic geotechnical has created probabilistic seismic hazard analysis, which is the most common and the best solution for estimation of seismic hazard. In this method, it is possible to include the uncertainties of various parameters, which depend on occurrence, in the results obtained from seismic hazard analysis (Tavakoli, 1993). This method of probabilistic seismic hazard analysis was proposed by Cornell for the first time (Cornell, 1977). In the present study, the method used for estimation of seismic hazard in a site has been taken from a known law of probability, which has been mentioned in various references (EERI, 1989). The probability that in a certain site, the strong ground motion parameter Y exceeds certain value of y due to a certain earthquake will equal to:

$$P[Y>y]=P[Y>y\mid X]P[X]=\int P[Y>y\mid X]f_x[X]dx$$

Where, X is vector sign including all effective random variables in Y and f_X is a probability density function which shows the uncertainty in random variable. In most cases, two variables are used in estimation of random parameter including distance *(R)* and magnitude *(M)*. Thus, the above equation will become as follow:

$$P[Y>y]=\iint P[Y>y\mid m,r]f_M(m)f_R(r)dmdr \qquad (1)$$

Where, $P[Y>y\mid m, r]$ is attenuation relation and $f_M(m)$ and $f_R(r)$ are density functions of magnitude and distance which should be individually determined for each seismic source concerning the specification of that source and its distance to site. Now, assuming that there are N seismic sources with seismicity rate of v_i, that can influence the site, the probability of exceeding of Y from y would be: (2)

$$\lambda_y=\sum_{i=1}^{N}v_i\iint P[Y>y\mid m,r]f_{Mi}(m)f_{Ri}(r)dmdr$$

The obtained λ_y can be interpreted as annual probability of exceeding y. assuming a Poisson distribution for temporal distribution of earthquake, the probability of exceeding from y value in T years would be:

$$R=1-e^{-\lambda_y T} \qquad (3)$$

Where, R is earthquake risk. In this study, 10% risk in 50 years (corresponding to return period of 475 years) was used for probabilistic seismic hazard analysis.

As this brief discussion indicates, probabilistic seismic hazard analysis is a valuable solution for modelling most uncertainties of earthquake including magnitude and distance. However, one should note that in some uncertainties, this classic method has remained silent such as in near fault. In fact, in no part of this method, the site being near or not being near to fault affect the calculations. In near fault sites, this can lead to unreliable estimations. To precisely explain this issue, it is required to first take a glance to near fault challenge and the role that attenuation relations play in probabilistic seismic hazard analysis and modelling of near field effects.

Near fault, a real challenge

If the site is located in a short distance (less than 10-15 km) from seismic source, it is considered near field. The vibrations of earth in near fault area lead to wide damages in the structures that even have preserved the earthquake bylaw. To this reason, the identification of the nature of earth vibrations near to seismic source has been proposed as a necessity and various studies have been done in this area (Ambraseys, 2003).

Consideration of near field effects in probabilistic seismic hazard analysis is a new topic such that one can even claim that it has remained intact. In fact, the only solution, which is currently available for modelling of near field effects in calculations of probabilistic seismic hazard analysis, is the use of attenuation relations with near field effects through which it is possible to model the behaviour of the structure as equivalent to near fault behaviour. However, the unpleasant event which might happen is that this general use of attenuation relations makes all points to be considered as near fault and to the same extent that not consideration of near fault yields illogical results, this method would also not yield reliable estimation. Anyway, it seems that the appropriate method of modelling near field effects should be done through attenuation relations path; however, the important point is how to use these relations in probabilistic seismic hazard analysis. To have a proper attitude toward this topic, first the nature of spectral attenuation relations should be taken into account more precisely.

The role of attenuation relation in probabilistic seismic hazard analysis

To perform probabilistic seismic hazard analysis, it is required to calculate the mean values of the ground motion in the intended site. The common method for obtaining mean values is the use of attenuation relations. Attenuation relation is a mathematical expression, which makes a certain parameter of ground motion dependent on one or several seismicity parameters related to occurrence of an earthquake such as magnitude and distance. These parameters are generally indicative of the specifications of seismic source, the path of wave propagation between seismic source, site, geological features and the soil of the location where site is located.

An attenuation relation is formed based on statistics and information from previous earthquakes and their regression calculation. Thus, it is natural that the specifications of the modelled earthquake in spectral attenuation relation transfer to the results of probabilistic seismic hazard analysis. In simple words, if in formation of attenuation relation, the statistics related to near fault earthquake are used, it is natural that one cannot expect to find any effect of near field effects in seismic hazard analysis.

Although, for a long time, the attenuation relations used in seismic hazard analysis lack near field effects, which is due to lack of certain attenuation relation for near fault, in recent years and by development of certain attenuation relations for near fault, it becomes possible to use these relations in probabilistic seismic hazard analysis. Moreover, it is almost possible to observe some results from seismic hazard estimation, which due to the use of these relations in probabilistic seismic hazard analysis; they claim the modelling of near field effects in estimation of earthquake.

However, it should be noted that the use of certain attenuation relations of near fault for all sites is not unproblematic in probabilistic seismic hazard analysis. For more explanation, it should be said that in the target territory, there are many sites with different distances from the faults of that territory. Some of these points are more than 15 km far from all faults, so naturally, they are not considered near fault in respect to none of them. In this way, near fault relations should never be used for estimation of their seismic hazard and the use of attenuation relations for near fault is not logical for them.

On the other hand, if a site distance from certain fault is less than 15 km, it is considered near fault and the use of certain attenuation relations for near field is justifiable. However, this site might be located in more than 15 km far from another fault and cannot be considered near fault for it, so the use of certain attenuation relation for near fault might not be logical for that fault.

This brief discussion shows that a logical estimation of seismic hazard in a territory that includes a set of near and far fault sites requires a logical combination of attenuation relation of near and far fault.

Finding such combination is the main aim of this paper. In fact, the aim of this paper is to make a proper estimation for object territory that includes both sites, i.e. near fault and far fault sites, by proper combination of attenuation relations of near and far fault. The first step for this combination is to introduce object territory, which will be presented in the next section.

Introduction of object territory and seismicity model

As previously mentioned, the object territory of this study, i.e. that territory for which probabilistic seismic hazard analysis will be performed, should be a territory including near and far fault sites with different distances with the faults to be able to fulfil the main objective of this study. This requires the selection of an object territory with many faults. Now that the aim is to select a territory with many faults, the best choice might be the selection of the most populated and important city of Iran, i.e. Tehran as object territory. Tehran is an area with high seismicity hazard that is surrounded by many faults and is considered as ideal object territory.

Here, Tehran territory is defined in 50.8 ° to 52.2 ° longitudes and 35.5° to 36.2° latitude. This area with approximate area of 10000 km^2 includes a territory from Karaj to Damavand in addition to Tehran. To investigate all seismicity factors, which might affect the target area; it is required to select an area surrounding this area as the plan territory. This bigger area is defined between 49.5 ° and 53.5 ° longitude and 34.0 ° - 37.0° latitude. The selection of the area with such extent as plan territory makes it possible to consider all elements and factors, which might affect the Territory of Tehran in seismic hazard evaluation. Figure 1 presents the plan territory and the defined area for Tehran.

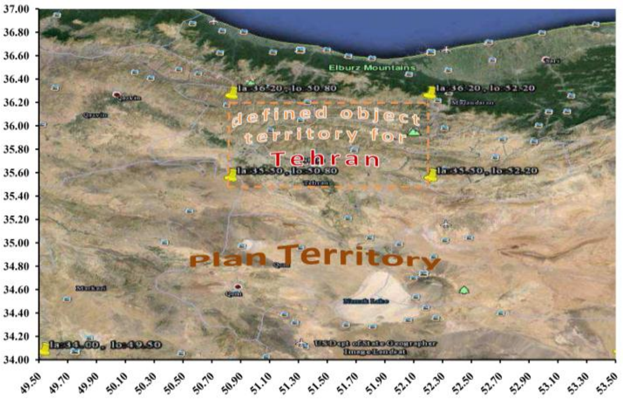

Figure 1. The plan territory and defined object territory for Tehran and the presentation of faults on it

In addition to the significant of the high number of faults in the plan territory, the other main point is to select model of geometry for its seismic sources. In fact, this study will find its proper nature and identity when the distance of sites from faults is precisely determined; this will make the use of linear model for seismic source geometry preferred to area model. To this end, the coordination of all present faults in Tehran were extracted by maximum accuracy and the seismic source model was formed by their modelling in software, as shown in Figure 2. It should be noted that the accuracy of determining coordinate of faults and drawing them is higher than the required accuracy in seismic hazard analysis and is specifically along with the objectives of present study.

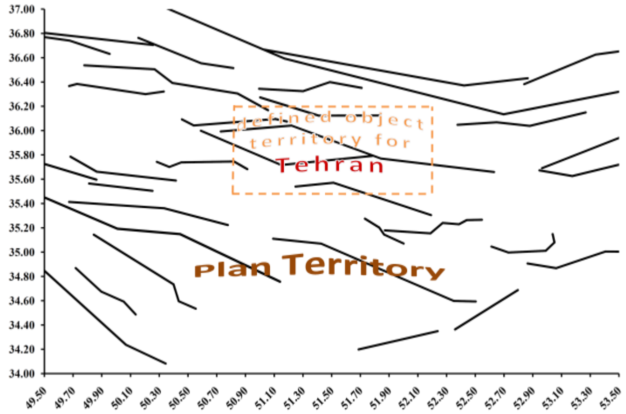

Figure 2. The modelling of faults in form of seismic sources with linear geometry in plan territory of Tehran

Selection of attenuation relations for near and far fault

Attenuation relations play key role in probabilistic seismic hazard analysis, indeed, in this study they play the most important role. Thus, their proper selection can guarantee the accuracy of the results. Two points should be considered in selection of proper attenuation relations; first, the selection of a spectral attenuation relation for a zone should be such that seism tectonics conditions of that zone to be seen in the mentioned relation; thus, the proper relation for that area is the one in whose construction, the recorded information of that area is considered. The second important point in this paper is that the mentioned relation should be available for near and far faults. By consideration of these two points, it is possible to achieve two valid spectral attenuation relations, i.e. Zare 1999 relation as far fault and Zare- Sabzali 2006 relation as near fault.

Zare attenuation relation 1999, far fault spectral attenuation relation

Based on the studies on accelerogram databases of Iran from all over the country and by selection of 498 three-component records and their correction in 1999, a new attenuation relation was proposed by Mehdi Zare for Iran. This attenuation relation is defined as follow based on Joiner and Boore (1981) model and use of response spectral values for 126 different periods (Zare, 2005):

$$\log S(T) = a(T).M + b(T).X - d.\log X + C_i(T)S_i + \sigma(T)P$$

$$X = \sqrt{D^2 + h^2}$$

In this model, *S(T)* is spectral acceleration in *T* period based on *m/s*^{2}, *T* is the selected period, *a* is magnitude coefficient *(M)*, *X* is focal length (such that *D* is the distance to center and h is the depth of focal length), *b* is inelastic attenuation coefficient with focal length *(X)*, *d* is the coefficient of geometry development *(log X)* which is considered as equal to *1*. C_i is the coefficient related to soil (s and *i* change from *1* to *4* for four types of site conditions) and σ is standard deviation of the logarithm of spectral acceleration, which in the condition of above mean, corresponding to probability of occurrence 84.1%, will be added to the second side of the equation by adding *P=1*, and, in mean condition it will be removed by adding *P=0*. The details of this model could be found in various references (Zare, 2005).

Zare 2006 attenuation relation, attenuation relation of near fault

To obtain this new attenuation relation which is for near fault, Joyner and Boore (1981), Fukushma and Tanaka (1990) and one-stage and two-stage regression on data were used. In this regard, some studies have been done on 89 three-component records in 1975 to 2003, which have been registered by seismic network of Iran. These experimental relations show the values of spectral acceleration as a function of moment magnitude, focal length and a constant parameter for site condition as follow (Zare and Sabzali; 2006).

$$\log S_a(T) = a_1(T).M + a_2(T).M^2 + b(T).\log R + C_i(T)S_i(T) + \sigma_{Sa}(T)P \qquad (4)$$

where, $S_a(T)$ is spectral acceleration in T period in respect to g, M is the moment magnitude and R is the distance from the center of earthquake and C_iS_i shows different site conditions. Furthermore, σ is the standard deviation of the logarithm of spectral acceleration, that in above mean (84.1%) by placing *P=1*, it is added to mean condition *P= 0*. The considered site conditions in this equation are similar to Zare attenuation relation (1999), such that by equalling Si parameter to zero and one, the intended site condition can be applied. This attenuation model was previously used by Joyner, Boore and Fumal (1997). More details can be found in (Zare, 2005).

Proposing a solution for modelling the near feild effects

The main idea of the present study can be defined in this section. As previously mentioned, routinely, seismic hazard analysis for object territory can be performed in two ways that can be called a scenario and as follow:

- Scenario 1: The use of attenuation relation for far fault, Zare 1999 for all sites of object territory
- Scenario 2: The use of attenuation relation for near fault, Zare 2006 for all sites of object territory

In case of using scenario 1, impossibility for modelling near field effects would happen for all points in proximity to fault and in case of using scenario 2 for all points, even far points from the fault would consider the near fault effects. These two scenarios lead to improper estimation of seismic hazard. The proposed solution for overcoming these deficiencies, which is called scenario 3, is the combined use of these two attenuation relations depending on their distance from the fault causing earthquake. Figure 3 represents this new solution better than any other explanation.

In fact, in this new scenario, by making some changes in the common method of probabilistic seismic hazard analysis, if the site distance from the fault causing earthquake is less than 13 km, Zare- Sabzali 2006 would be used; otherwise, Zare 1999 attenuation relation will be used for estimation of seismic hazard analysis. It is obvious that this displacement of attenuation relation for a certain site in respect to its distances from all existing faults would frequently happen. Such solution can guarantee two cases; first, when the site distance from the fault is less than 13 km, the near fault effects will be modelled and when the site has considerable distance from fault, no near field effect will be seen in estimation of its seismic hazard. To investigate the accuracy and precision of these three different ideas in probabilistic seismic hazard analysis, in the next step, the probabilistic seismic hazard analysis would be performed for territory of Tehran under three defined scenarios.

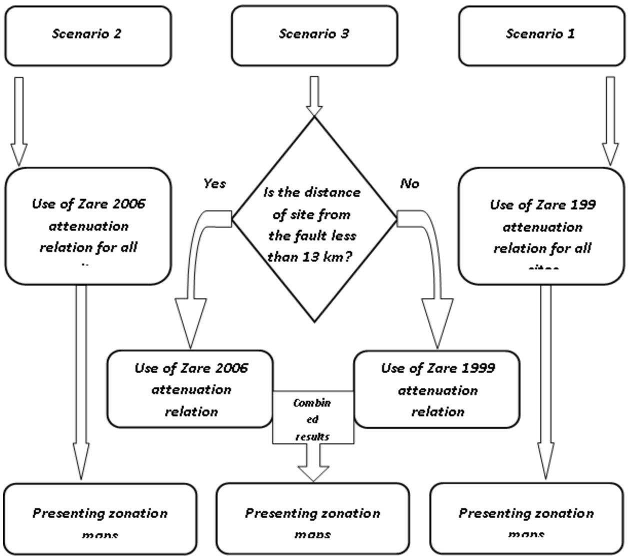

Figure 3. The work procedure in three scenarios used in this study

RESULTS AND DISCUSSION

The results of territory for three different scenarios

What was mentioned in previous sections will be used in this section to perform a probabilistic seismic hazard analysis for object territory of Tehran. As previously mentioned, the probability of intended occurrence in this analysis would be risk of 10% during 50 years (corresponding to return period of 475 years) and the site condition for all sites has been considered as bedrock. In Figure 4 to 6, one of the most important obtained results from probabilistic seismic hazard analysis, i.e., seismic zonation maps, is peak ground acceleration or PGA can be seen, each has been calculated and drawn for object territory under scenarios 1, 2 and 3.

Figure (4), i.e. the PGA in object territory by return period of 475 years without consideration of near field effects for Tehran territory, is in fact that familiar map which is considered corresponding to seismic hazard seismic zonation map in standard 2800 and is currently the base of construct designing in this territory. The values of this map can be a criterion for evaluation of the accuracy of the results of this analysis that undoubtedly indicates the precision of the present study. The results of this scenario are completely consistent with the results of the most credible studies on estimation of seismic hazard in Tehran (for example, Berberian (1985), Tehrnai Zadeh (2004) and Khoshnoodi (2002) and can be considered as a proper criterion for evaluation of the accuracy of other results of present study. In this study, the minimum PGA value is 0.206 g and the mean value has been estimated to be 0.298 g which seems to be logical. The main deficiency of the present map is the maximum estimated value, i.e. 0.444g that essentially lack argumentation. In fact, such estimation is a kind of extrapolation that lacks required deficiency and this value is essentially unreliable regardless of being small or big.

Figure 5, i.e. PGA in object territory by return period of 475 years and assuming near field effects for all points of Tehran territory, seems to be overestimation. This is especially highlighted in minimum value, i.e. 0.341g and mean value, i.e. 0.386g, and has represented itself in maximum value 0.450g to a lesser extent. The results of the present study are completely consistent with this scenario. This scenario assumes that all points, regardless of their distances from the fault, are near fault; thus, it is natural that such assumption leads to extraordinary increase of estimated hazard for all far points from the fault with the minimum point among them and this tangibly is effective on mean. On the other hand, one should not expect that this assumption to be much effective on maximum point, which is similar to near fault compared to most faults in terms of nature.

Now, it is time to study scenario 3, i.e. the proposed solution of this paper that is combined use of both attenuation relations for near and far faults, the results of which have been represented in figure (6). In a general judgment it can be said that although this combined map is a combination of two maps of previous scenarios and accompanies them in determination of minimum and maximum zones, the precision in its minimum, maximum and mean values can guarantee considerable results.

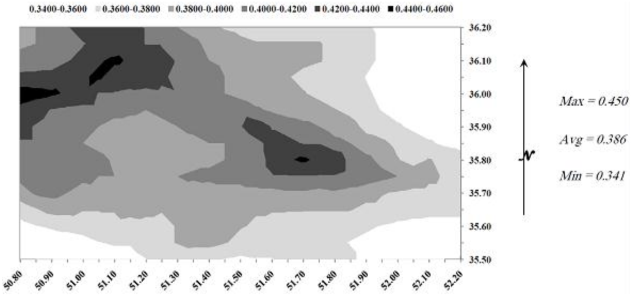

Figure 4. PGA map with return period of 475 years for objet territory under scenario1

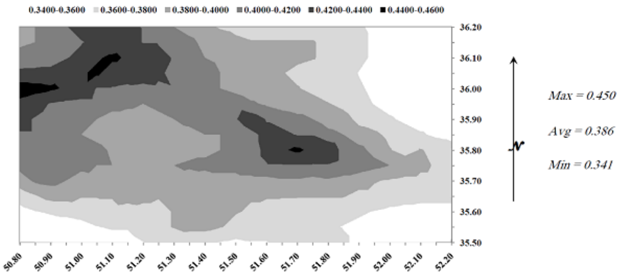

Figure 5. PGA map with return period of 475 years for object territory under scenario 2

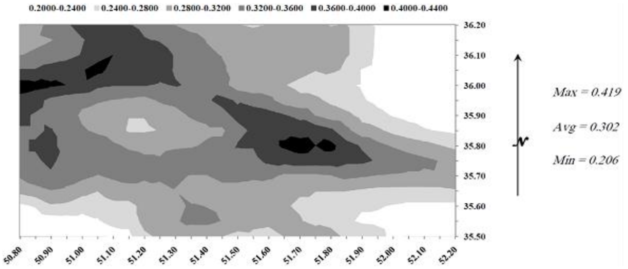

Figure 6. PGA map with return period of 475 years for object territory under scenario 3

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The minimum value in scenario 3, i.e. 0.206 g, is exactly the minimum in scenario 1. Thus, concerning the logic of scenarios and the fact that the minimum point is certainly a point, far fault indicates the proper estimation of the value in addition to being indicative of the accuracy of calculations. However, the interesting point has happened in maximum value of scenario 1. It is considerable that this value has been obtained by combination of two relations; however, it is 10% below those two values. There is just one justification for this event, in maximum point, the estimation has been done in the most reliable form such that in cases where the mentioned point was near fault, the attenuation relation for near fault became activated and estimation, which is reasonably a significant value, has been properly done. In other cases when this point is not considered near fault, instead of using attenuation relation for near field, which mistakably increases the estimation, far field attenuation relation will be used. In this case, despite scenario 1, where estimation will be in form of unreasonable extrapolation, a logical interpolation will happen and a bit would be added to estimation of hazard, thus the logical value 0.419g would be constituted as maximum value. It might be the case that the most valuable result of this scenario is the increase of mean value in respect to scenario 1 and meanwhile a tangible reduction of maximum value in respect to that scenario, which can be considered as the most important reason for the appropriateness of the proposed solution in this study for reliable estimation of seismic hazard.

The comparison of results of three different scenarios

Although the results of previous section can be considered as a comparison of the results of three defined scenarios of this study, to some extent, an ideal option for the mentioned comparison is to compare the uniform hazard spectra of these three scenarios. Uniform hazard spectrum is a response spectrum where the probability of occurrence of all points is the same in different scenarios. Uniform hazard spectra are on contrary to those spectra that are scaled by the ground motion parameters. Despite the scaled spectrum, the form and shape of uniform hazard spectrum is not constant and each point can have its certain spectral shape. The form and values of uniform hazard spectrum range are subject to magnitude, distance and the probability of occurrence, while these parameters are ineffective on the scaled spectrum. In construction of uniform hazard spectrum, response parameters are directly used. Thus, these spectra estimate the response of structure and the resulting force of earthquake more logical than scaled spectrum (Adams, Halchuk, 2003).

Such spectra are good instrument for comparison of three scenarios in addition to being proper instrument in seismic hazard analysis. The main reason for this is the dependency of uniform hazard spectrum on the site and the distance of the site from the fault causing earthquake. In fact, despite the scaled spectrum that has constant form, the form of uniform hazard of a site might change according to its distance from the fault. This is a good criterion for evaluation of the accuracy of the results of three scenarios and their comparison.

To this end, two points with completely different seismicity conditions, one a point with coordinate of 51.70 longitudes and 35.80 latitude which is near fault and has high seismicity level, and another point with coordination of 52.15 longitudes and 36.00 latitude with certain distance from fault with relatively low seismicity level have been selected. The uniform hazard spectra for both points have been defined by probability of occurrence of 10% in 50 years (return period of 475 years) in bedrock condition under three scenarios and drawn in 13 periods of zero second (which is PGA), 0.10, 0.16, 0.20, 0.24, 0.30, 0.40, 0.50, 0.60, 0.80, 1.00, 1.50 and 2.00 seconds. Figure 7 shows the spectrum related to maximum point and Figure 8 shows the spectrum related to minimum point in the same scale, these two figures can be indicative of certain issues.

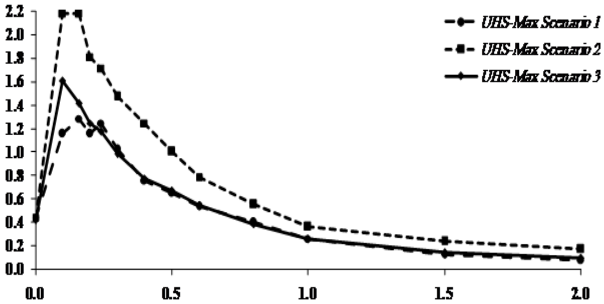

Figure 7. Uniform hazard spectrum for the point with maximum seismic hazard in territory of Tehran under three defined scenarios

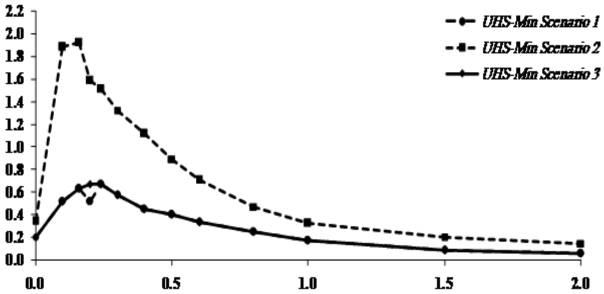

Figure 8. Uniform hazard spectrum for the point with minimum seismic hazard in territory of Tehran under three defined scenarios

In maximum hazard point, the difference of three spectrum obtained from three scenarios is completely clear. An important point concerning these three spectra is that the three defined scenarios have been effective on spectral range much more than PGA. A detailed look at the spectrum makes it clear that the spectrum of scenario 2, i.e. the spectrum that is obtained from attenuation relations of near fault, has been overestimated as predicted, which is due to consideration of near field effects for all distances.

Furthermore, it is observed that the spectrum of scenario 1, i.e. the spectrum obtained from certain attenuation relations for far field has also taken the minimum value. In maximum point of scenario 3, i.e. the spectrum obtained from the combination of attenuation relations, has an interesting condition.

Furthermore, it can be observed that the spectrum obtained from attenuation relation of far fault has the minimum value. In maximum point, the spectrum of scenario 3, i.e. the spectrum obtained from the

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combination of attenuation relations, is very interesting. It means that in short periods, it is affected from near fault and is tangibly longer than the spectrum of scenario 1, however, in long periods, it is drawn completely on this spectrum. This is completely consistent with the theory on near fault that explains short periods are affected by near fault.

The obtained results about three uniform spectra of minimum point are completely logical and interesting. In this point which is not absolutely near fault, the spectrum of scenario 2 has been inexplicably overestimated and two spectra of scenario 1 and 3 have been coincident. In fact, in scenario 3, the near fault relation is not activated and except correction of dent point of spectrum in short periods, other periods are coincident on the spectrum of scenario 1.

CONCLUSION

The present study aimed at introducing a solution for proper modelling of near field effects in classic method of probabilistic seismic hazard analysis. This new method is based on the combination of attenuation relations for far and near fault in respect to their distance. In fact in the classic method of probabilistic seismic hazard analysis, for estimation of risk and hazard in any site, attenuation relation of far fault can be used or near fault relations which are the new generation of these relations can be used.

The results of this study showed that in case of using attenuation relation of far fault for all points, although estimation is well done in most points lacking near fault condition, the estimation in near fault points which is done through extrapolation would be unreliable. On the other hand, the use of attenuation relation of near fault is effective in modelling of the effects of this area; however, the estimation by these relations would be very high. The reason might be the assumption of near fault condition for all sites. However, the proposed solution in this study can acceptably overcome this problem and model near field effects in probabilistic seismic hazard analysis.

In this new solution, by making some changes in classic method of probabilistic seismic hazard analysis based on the site distance from the fault, both attenuation relations were used such that in calculations, if the site distance from the fault was less than 13 km, near fault attenuation relation will be used and if it reached more than 13 km, the attenuation relation of far fault would be used. In a general judgement, the seismic zonation maps in this method were calculated optimally. Maximum value was neither determined by extrapolation not it was overestimated. Furthermore, the minimum value was completely conformed to the obtained value from attenuation relation of far fault and the mean value was a bit higher, both were consistent with the philosophy and logic of near field effects. Furthermore, the uniform hazard spectrum obtained from this new solution seems to be logical and reliable.

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