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Using the Piano Keys Sound as Artificial Accelerations

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ABSTRACT

Today, one of the most important issues in designing of structures is their reliability and functional design. In order to obtain reliability, different parameters of the earthquake history are considered as probabilistic and that their effects on the reliability of the structures. In fact, it is necessary to consider all possible scenarios in the earthquake event in the probability of failure of the structure, which is recorded using natural ground motions. In response to this engineering requirements, the use of simulated artificial earthquake records is one alternative. Therefore the most important point in using artificial records is to use a model that can more effectively capture the effective parameters in earthquake production. In this case, by obtaining uncertainties regarding the efficient parameters in that model, it is possible to produce an accidental earthquake production. In this study, the use of piano keys was applied as an artificial record. To achieve this goal, 6 pieces of a piano-sounded that has an initial landing, up and then secondary landing are selected. To compare the results, the 6 ground motion records of near field with pulse effect and 6 ground motion records of far field for soil type II was extracted from the PEER site . In order to compare the records, the response spectrum and their correlation were used. The results showed that the correlation between the selected artificial records for the far field of faults is more than near field.

Keywords:

Piano keys sound, Artificial acceleration, Response spectrum, Frequency content, Correlation coefficient.

1. Introduction

Bartolomeo Christophorus invented the piano in about 1700 in the city of Padova, Italy. But the new invention of Christophy remained nearly unknown for about a decade until in 1711 an Italian author wrote an article about it, later translated into German and published extensively. This article also included a piano mechanism diagram, and most of the piano-makers started their work on this article. Before the invention of the piano, the older version was called Harpsichord [1]. Based on stochastic models, different methods are developed to generate artificial acceleration. As an example, the method of synthesizing sinusoidal waves is one of the methods for generating artificial acceleration which was first introduced in 1998 to simulate earthquake records based on a random algorithm [2].Evaluating the earthquake response spectra of a region has shown that although it is not possible to definitively identify the shape of earthquake records- even within a certain range of time intervals - in some cases, the response spectra associated with them are generally very similar. So it can get a fairly definite pattern for the response spectra of a particular region. For this reason, researchers have been able to achieve artificial records by drawing such response spectra on the design spectrum [3].However, the problem in many generated earthquakes was the difference between the frequency content and the dominate frequency of the generated earthquakes with actual earthquakes. It followed a variety of patterns including: Random pulse pattern; shot noise pattern; Modified static pattern by first, second and continuous order filters and etc were used to produce such records that each pattern had its own specific characteristics. Another way is to use the spectral density function of power, that most important of them is the Kanai-Tajimi model and some researchers have works based on this model in order to generate the artificial earthquake records [4]. Subsequently, some researchers were interested to use one or a combination of multiple neural networks with different decision functions to produce response spectrums corresponding to the design spectrum [5-11]. Alongside neural networks, various mathematical theories were applied in this area. For example, the wavelet theory, like February conversions, has a specific mathematical basis and it is used to solve various problems such as solving partial differential equations. Also in engineering applications, this theory has rapidly expanded into electronic engineering and especially signal processing and now, it's application extending to such an extent that it is a powerful tool in time-domain analysis. If this is done for the records studied and finally the February conversion of each balance is calculated, it will be observed that the above conversion will only cover a certain range at each level. This is one of the prominent features of Violets, and by observing the Fourier transforms, a particular alignment for all records can be considered as formal pattern. In fact, each wavelet alignment has an appropriate pattern in the form of frequency transforms, as used in the generation of artificial acceleration [12-14].Also it has been shown that the Fourier transform of each Violet balance covers part of the Fourier transform of the primary signal. Therefore, the frequency range of each alignment is easily determined and this method produces artificial records consistent with the Fourier spectrum [15,16]. The point is that if a record for a design spectrum was available, it will be able to calculate the wavelet coefficients using a matrix analysis [17]. In this research, the sound of the six random parts of playing a piece of piano that has the initial landing, up and down the secondary is randomly selected and considered as artificial records. In this selection, we try to consider the effect of the interference of the notes on each other, which helps to overcome the sound. In order to verify the accuracy of artificial records, it is necessary to compare the data with actual earthquake records.

Therefore, for the purpose, 6 near-field records with pulse effect and 6 far-field records have been selected for soil type II.

2. Methodology

2.1. Piano Keys Selection

The piano hammers are attached to the piano keys by a series of delicate levers. The set of these levers and hammers is called operon or piano. The task of this unit is to increase the acceleration of the hammers in the collision with the wires, and to control their return reaction after the collision with the wires. The hammer head is usually covered with a layer of wool or similar natural or synthetic fibers to improve the sound quality of the piano. Piano sound quality is also affected by other factors such as sound quality and so on. The sound of the piano is hammered into a wooden box as a result of the hammering of metal wires. These hammers move as the keys are pressed. The piano strings are attached to a so-called "sound board" which has a sound-enhancing role. The piano has the highest acoustic amplitude among the usual instruments (with the exception of the church organ), as in its current form it typically has about seven octaves and is capable of producing frequencies from about 1 to 2 Hz, while being the violin instrument. It can only produce about five octaves, and most readers can only read less than three octaves. There are 2 white keys per octave for the piano; In addition to the white keys, there are black keys between some of the white keys. There are no white keys between the white and the fa and May and thirty two black keys. Each black key on the piano is Dizzy's note for the note on its left white key (that is, the black key is on the right of that white key), and a net note for its right white key (that is, that key). Black is to the left of the white key). Digital pianos are two to three octaves less than Grand and Royal pianos.

2.2. Data Set

In this study, six randomly selected pieces of sound from a piano piece were randomly selected. In this choice we try to consider the effect of the interference of the notes on each other which helps to modulate the sound. Figure 1 shows the audio diagram of this fragment extracted by MATLAB software.

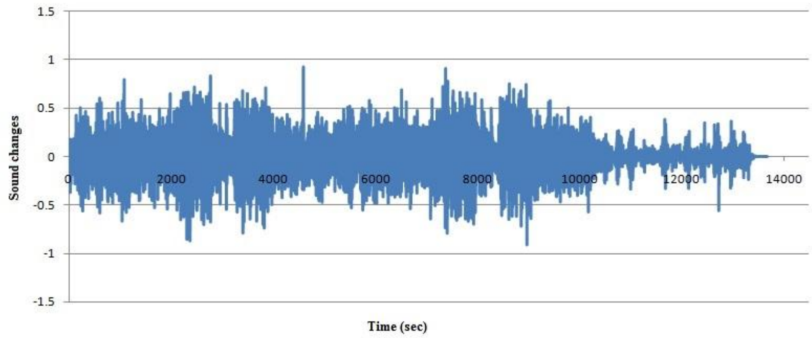

Figure 1. Diagram of the sound changes to the time of the selected piece.

Selected from the above plot are 6 pieces with primary landing, downhill and secondary landing. The diagram for one of these patches is shown in Figure 2.

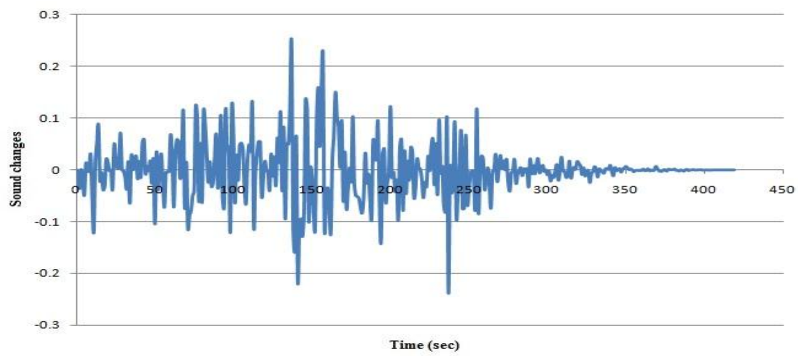

Figure2. Diagram of the sound changes versus time of a piece of the selected piece.

2.3. The Response Spectrum of Sounds

After selecting the records for the study in question, the response spectra of each are first plotted to evaluate and compare them with the original earthquake records. SeismoSignal software was used to do this. Figure 3 shows a graph of these spectra. It is noteworthy that for the correct comparison, the spectrum is scaled to the maximum value such that the acceleration on the bedrock is equal to all records.

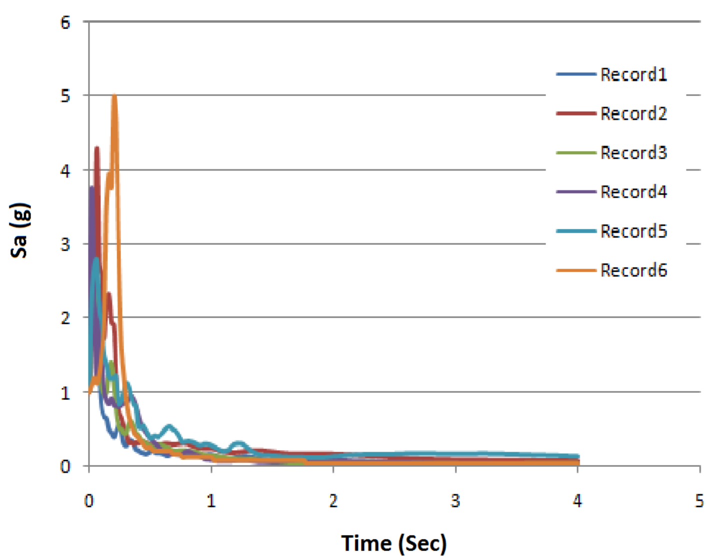

Figure 3. Chart of the response spectrum of 6 selected synthetic records.

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2.4. Select Earthquake Records

In this study, in order to verify the accuracy of synthetic records, it is necessary to compare the data with real earthquake records. Therefore, 6 near field records with pulse effect and 6 far field records for second type soil have been selected from Peer site [18]. Information on the records of the records of both areas is shown in Tables 1 and 2.

Table 1. Specifications for the records selected for the near field

No.	Record number	Incident name	Station name	Date of occurrence	Effective movement time (s)	Magnitude (Richter)	Distance to fault (km)	Fault type	Shear wave velocity (m / s)
1	285	Irpinia,Italy-01	Bagnoli Irpinio	1980	19.6	6.9	8.14	Normal	649.67
2	292	Irpinia, Italy-01	Sturno (STN)	1980	15.2	6.9	6.78	Normal	382
3	802	Loma Prieta	Saratoga-Aloha Ave	1989	9.4	6.93	7.58	Reverse Oblique	380.89
4	1052	Northridge-01	Pacoima Kagel Canyon	1994	10.1	6.69	5.26	Reverse	508.08
5	3473	Chi-Chi, Taiwan-06	TCU078	1999	7.4	6.3	5.72	Reverse	443.04
6	4228	Niigata, Japan	NIGH11	2004	12.2	6.63	10.2	Reverse	418.5

Table 2. Specifications for the records selected for the remote area

No.	Record number	Incident name	Station name	Date of occurrence	Effective movement time (s)	Magnitude (Richter)	Distance to fault (km)	Fault type	Shear wave velocity (m / s)
1	1	48	Lytle Creek	Puddingstone Dam (Abutment)	1970	10.2	5.33	29.42	Reverse Oblique
2	2	63	San Fernando	Fairmont Dam	1971	14.4	6.61	25.58	Reverse Oblique
3	3	121	Friuli, Italy-01	Barcis	1976	10.4	6.5	49.13	Reverse
4	4	155	Norcia, Italy	Bevagna	1979	14.9	5.9	31.43	Normal
5	5	330	Coalinga-01	Parkfield - Cholame 4W	1983	13.6	6.36	45.49	Reverse
6	6	444	Borah Peak, ID-02	HAU	1983	12.7	5.1	48.43	Normal

The response spectra of the records selected for the near and far domain for comparison with synthetic records from the piano keys are shown in Figures 4 and 5, respectively.

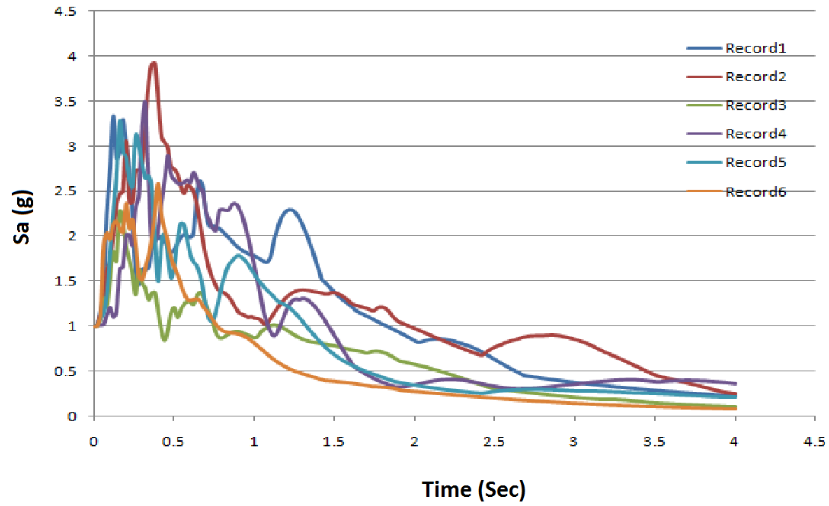

Figure 4. Diagram of the response spectrum 6 records selected for the near field.

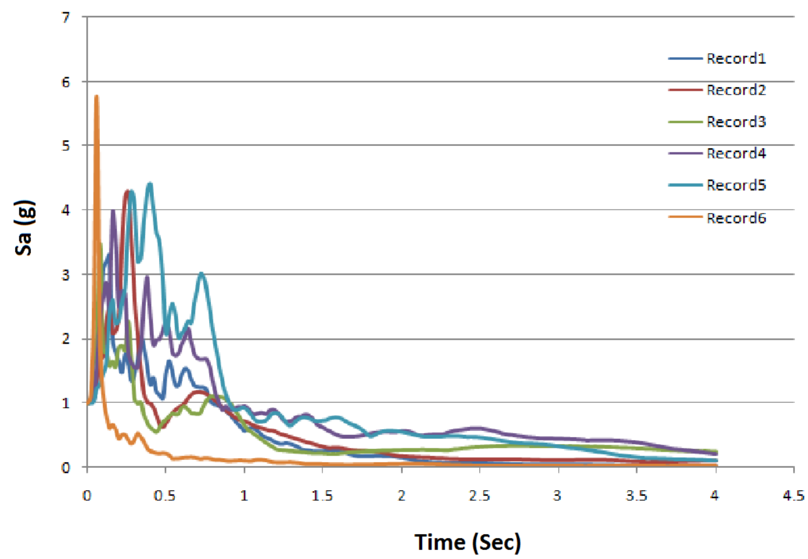

Figure 5. Chart of Response Spectrum 6 records selected for the far field.

3. Results and Discussion

3.1. Performance Evaluation Criteria

A comparative coefficient is needed to evaluate and compare synthetic records from piano keys with major earthquake records. The results on different data show that the best factor for evaluating independent indicators in statistics is the correlation coefficient. Correlation coefficient is a statistical tool for determining the type and degree of relationship of one quantitative variable to another. Correlation coefficient is one of the criteria used to determine the correlation of two variables. The correlation coefficient indicates the severity of the relationship as well as the type of relationship (direct or inverse). This coefficient is between 0 and -0 and is zero if there is no relationship between the two variables.

Spearman correlation coefficient is used if the data are small and assumed to be unreasonable. The correlation coefficient calculated on the basis of data rank was calculated by Spearman. The difference between regression and goal-based correlations is that the correlation models aim to investigate the relationship of two or more variables while regression seeks to predict one or more variables based on one or more variables. Since regression is based on past data, it is called regression ie return to the past; therefore, the correlation objective shows the magnitude and severity of the variables relationship, but regression provides an equation for predicting variables. In fact, the difference between regression and correlation based on the method is that what makes the outputs of the regression and correlation results is that in the correlation the effects of variables are always measured in pairs but in a regression model the effects of variables are examined simultaneously. Can be. That is, the correlation of the variable X with the variable Y does not correlate with the presence or absence of the variable Z, but in the regression the effect of variable X on the variable Y depends on the presence or absence of variable Z. The relation of determination of this correlation coefficient used in this study as follows.

$$Corr(X,Y) = \frac{Cov(X,Y)}{\sigma x \sigma y} = \frac{E[(X-\mu x)(Y-\mu y)]}{\sigma x \sigma y} \quad (1)$$

In this relation E is the operator of mathematical hope, Cov means covariance, Corr is the usual symbol for Pearson correlations, and σ is the standard deviation symbol.

3.2. Data Analysis

After extracting response spectra for synthetic records, the near and far fault records use the correlation coefficient to determine the relationship between them. MATLAB software is used to do this. A comparison of the results is presented in Tables 3 and 4, respectively.

Table 3. Comparison of Correlation Coefficient between Records Extracted from Sound and Near Fault Records.

Record number	1	2	3	4	5	6	Average
285	0.3318	0.4803	0.4771	0.3892	0.4804	0.5125	0.4452
292	0.2799	0.351	0.4543	0.4612	0.4801	0.4685	0.4158
802	0.4675	0.5987	0.6259	0.549	0.6293	0.6484	0.5865
1052	0.2575	0.2558	0.3828	0.36	0.414	0.3194	0.3316
3473	0.3865	0.4935	0.5735	0.5139	0.5879	0.6373	0.5321
4228	0.5114	0.6249	0.6721	0.6394	0.7081	0.6548	0.6351

Table 4: Comparison of Correlation Coefficient between Records Extracted from Sound and Remote Fault Records

Record number	1	2	3	4	5	6	Average
48	0.5199	0.6598	0.6836	0.6424	0.7314	0.6426	0.6467
63	0.4987	0.5837	0.6318	0.6023	0.6829	0.7621	0.6269
121	0.6738	0.7836	0.7645	0.7152	0.8238	0.7097	0.7451
155	0.4314	0.6117	0.6469	0.5752	0.6548	0.6993	0.6032
330	0.294	0.3331	0.4553	0.4714	0.4958	0.4448	0.4157
444	0.8445	0.8551	0.694	0.6249	0.823	0.3763	0.7030

The comparison of the tables shows that the most correlations are between the near-field records with the Loma Prieta, Niigata, Japan and Chuetsu-oki, Japan earthquakes. Also, the least correlation was obtained for the Northridge earthquake. Also for the far field, Friuli, Italy-01 and Borah Peak, ID-02 had the highest and Coalinga-01 had the least correlation among the selected records. The results of these two tables show that the degree of correlation between the artificial records selected for the fault-free zone is more strongly correlated with the near-fault state.

4. Conclusion

The comparison between near-field recordings and synthetic recordings derived from piano sound showed that the highest correlation with the Loma Prieta, Niigata, Japan and Chuetsu-oki, Japan earthquakes was about 60%. Also, the lowest correlation for Northridge earthquake was about 30% and also the comparison between remote area records and synthetic records derived from piano sound showed that Friuli, Italy-01 and Borah Peak, ID-02 70% had the highest correlation. Coalinga-01 had the lowest correlation of about 40% among the selected records. The results also showed that the correlation between the selected synthetic records for the faraway fault zone is higher than the near fault state.

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