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The Using Simplified Accelerogram Based on the Concept of Hit Load

Fereydoon Omidinasab
Department of Civil Engineering, Lorestan University,
Khorram Abad, Lorestan, Iran

Abstract: Time history analyzing method is one of accurate methods of assessing structures' behavior against earthquake. In spite of this, this method requires spending plenty of time and volume of calculations especially in structures with high freedom degrees number. One method is proposed in this article to simplify used accelerograms in time history analysis using the concept of hit loading. In this proposed method, accelerogram is equalized to a limit number of pulse sequence which is entered to structure in various times. The number of these pulses can be more or less depending on the required accuracy and length of earthquake record and main structure period. The severity of each one of hits is equivalent to the rate of energy of earthquake is a part of record that mentioned pulse is equalized instead of that as an initially recommendation in this study, the distance of two sequenced points with zero velocity in earthquake record is considered as the limitation of each pulse in a way that the area under the curve of accelerogram be equal with the rate of equivalent strike. The time of applying this hit is also considered in center of mentioned area under accelerogram. Through adding structure responds against each one of hits , structure respond will be calculated in different moments, using a number of various samples with periodic times and different rates, the efficiency of proposed method has been shown. Numerical results show that maximum displacement spectrum resulted from this method has an approximate error of 5% while the volume of done calculations has been reduced more than 15 times toward time history with main record.

Key words: Analyzing time history, accelerogram, hit loading, numerical integration, proposed method

INTRODUCTION

Time history analysis method is considered as the realest method of seismic respond of structural systems because structure is placed exactly under earth's real acceleration in this method and structure's respond will be calculated. Naturally using this method requires doing above calculations volume and spending plenty of time. In order to this various methods have been proposed by researchers to be able to achieve structure's maximum seismic respond through less calculations' volume. In this method earthquake records are divided to a huge number of sequenced hits and structure's respond will be computed against each one of hits and with expanding adding on sequenced hits of structure's respond (Duhamel integration method). Time steps used in time history analysis are usually selected among 0.005-0.002. As a result the number of high computing steps in this method causes increasing the volume of calculations and its time consuming. Wang can be mentioned as one of the first people who have worked in the field of simplifying the method of time history analysis in 1970's (Wang, 1975) Other various people have worked in this field in recent years that of course each one of their focus had been on one particular structure. For example Kitiyodom et al in 2004 have proposed a simplified dynamic analysis method for pile foundations under seismic load. Oskouei and McClour (2009) have proposed a method for analyzing telecommunication towers under earthquake excitation Kousta have proposed a simplified time history analysis method using plasticity theory (Costa *et al*., 2005). Soroushian (2008) proposed a method for analyzing time integration through steps so much bigger than excitation steps in a way that with steps approximately 5 times bigger than common time steps, no computational error is observed. Fproughi and Hosseini have proposed a method for analyzing fast time history of linear systems based on modified Fourier transform photo.

A method is proposed in current article based on hit load concept in order to decreasing the volume of necessary calculations in time history analysis. Accelerogram is divided to a finite number of sequenced hits in various times in this method in a way that the rate of input energy to structure under the main earthquake is equal with the rate of input energy derived from these sequenced hits. It has been shown through various

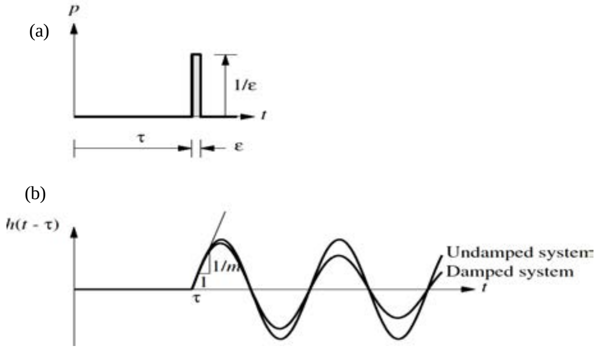

Fig. 1: a) Unit hit load, b) structure respond under the effect of unit hit load (Chopra, 1995)

examples that the results of this method decrease an error >5% of the volume of calculations among 10-15 times.

Time history analysis of structure under arbitrary excitation: Figure 1a shows a hit load with short time length of ε that is applied to structure in moment t = t with severity p(t) = 1/e. As result if the value of ∈ goes to zero, hit magnitude will be constant and equal to unit and so it is called unit's hit load. Based on newton second law, structure respond under this hit excitation is equal with applying primary speed equal to 1/m in moment τ. As a result if it is assumed that structure doesn't have any primary displacement before applying power (u(t) = 0) so structure's respond will be as follows (Fig. 1b):

$$h(t-\tau) = u(t) = \frac{1}{mw_D} e^{-\xi w_n (t-\tau)} \sin[w_D(t-\tau)](t^3 t) \quad (1)$$

Now if structure is under arbitrary excitation same as Fig. 2, load can be assumed as a number of sequenced hits with magnitude of p(t)dt in moment τ. The total of these responds during the time t is equal with structure's respond under arbitrary excitation that is so-called convolution integral. For single freedom degrees structures this equation will be as follows which is called Duhamel integral:

$$u(t) = \int_0^t P(\tau)h(t-\tau)d\tau = \frac{1}{mw_D}\int_0^t P(\tau)e^{-\xi w_n (t-\tau)} \sin\left[w_D(t-\tau)d\tau\right](t^3\tau) \quad (2)$$

Calculating displacement rate in whole time of t isn't usually required for designing purposes and only achieving maximum displacement is adequate because the maximum internal creating efforts in structure depends on structure maximum relative displacement. On the other hand it can be shown that if a single degree of freedom structure under pulsed excitation is placed with finite time (t_d) and magnitude the rate of its maximum displacement toward its static displacement depending on the form of pulse is same as Fig. 3.

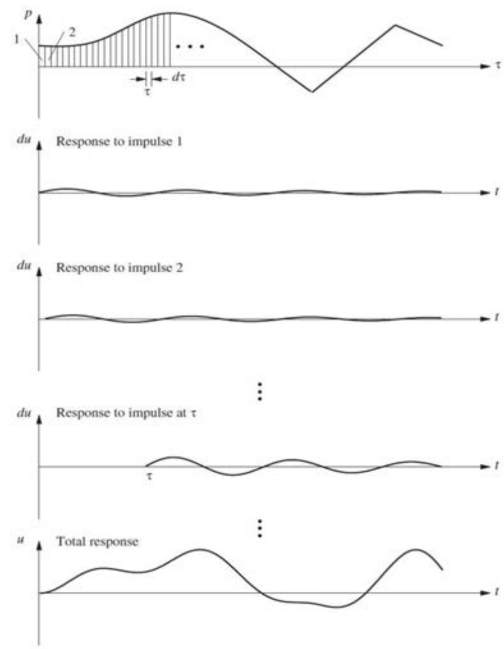

Fig. 2: The schematic convolution integral (Chopra, 1995)

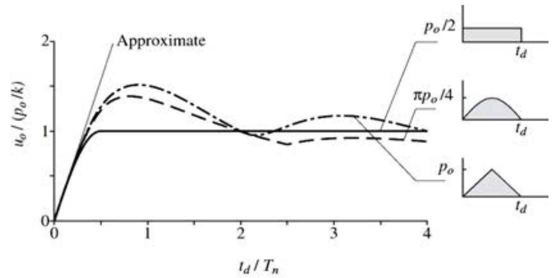

Fig. 3: Doubt spectrum for three pulse powers with equal area (Chopra, 1995)

This diagram is so-called doubt spectrum. As it can be observed from Fig. 3 when it is ((t_d/T_n)£0.25), maximum respond doesn't have any dependency to pulse power and only depends on pulse power magnitude. As result if we show the magnitude of pulse power with letter I, power magnitude and hit power respond equivalent of that can be achieved out of Eq. 3:

$$I = \int_0^{t_d} P(t)dt \quad (3)$$

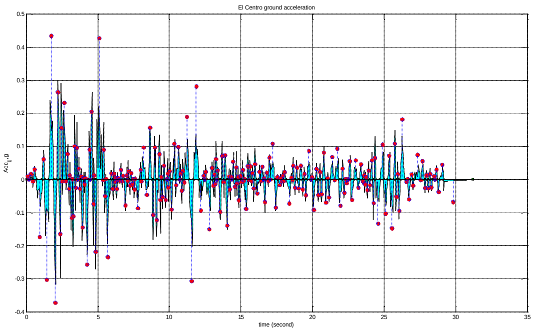

Fig. 4: El Centro earthquake acceleration diagram with hit loads equivalent

MATERIALS AND METHODS

Modeling earthquake accelerogram as finite hit loads Earthquake accelerograms are usually recorded in time steps of 0.005, 0.01, 0.02 sec as a number. Similarly, used steps are done in structure's dynamic analysis are usually done in these very time steps. As result for accurate analysis of time history of structure under an earthquake it averagely requires analysis among 1000-6000 time steps. On the other hand, it should be noticed that the time of main period of structures are usually bigger than these values while the maximum displacement of structures against earthquake is more derived from earthquake record main pulses and the rest of earthquake won't affect significantly maximum respond. According to mentioned information and previous section information in this part, a method is proposed for simplifying earthquake records in a way that through significant decrease of calculations' volume, the accuracy of results will be high in an acceptable value.

In proposed method for simplifying earthquake record, the distance between two sequenced points on accelerogram which have zero velocity is considered as a power pulse. As result earthquake record is a set of negative and positive pulses with various magnitudes. Now based on Eq. 3 the value of severity of each pulse can be calculated and instead of that, a hit equivalent with the rate of severity equivalent with that very pulse can be used. An appropriate approximation, the time of applying time of each one of these hit loads is considered in a time equivalent with the center area of each one of pulses.

For example, in Fig. 4, El Centro earthquake acceleration record has been shown with its equivalent hit loads. In another word in this proposed method, instead of using earthquake real record, finite number of hit loads are used in various times. It is noticeable that here in order to compare respond's time history diagram with real results completely, small hit loads are eliminated. In spite of this in practical works, small hit loads (for example with smaller severity than 0.25 PGA) can be eliminated. As it is observed the number of these small hits is very more than other hits and even lack of their consideration can make this method even more simplified.

RESULTS AND DISCUSSION

Numerical example: In this study for investigating the efficiency of proposed method for fast analyzing structures' seismic responds, El Centro earthquake acceleration time history record for the analysis of structures one degree of freedom with attenuation of 2 and 5% are used. in order to this one degree freedom structure is first analyzed accurately under El Centro earthquake and then under sequence hit loads equivalent el Centro earthquake, structure's time history respond will be obtained.

In Fig. 5, structure's respond with 2 sec period and attenuations of 2 and 5% using accurate method and proposed approximate method have been shown. As it can be observed the results of accurate method and approximate method are aligned with each other with an extremely appropriate accuracy and proposed method can well obtain the process of structure's seismic respond. In mode with attenuation of 2% maximum respond of accurate answer is equivalent with 13.65 cm while this respond in approximate method is 14.16 cm. This shows that approximate method has 3.8% of error. The results of maximum response of this structure with 5% damp for accurate and approximate analyses are respectively 18.97 and 18.99 that in this mode the error percentage is equal to 0.1%. These results show that in this particular earthquake, as the value of attenuation increases approximate method has relatively more suitable accuracy.

In Fig. 6, similar results have been shown with shorter period time of 0.5 seconds and attenuations of 2 and 5%. This shows results in these figures also show the general behavior accuracy of proposed method. In this mode for structure with attenuation of 2% accurate and approximate maximum respond are respectively 6.79 and 7.40 cm that shows error level of 9%. When attenuation is 5% these numbers are respectively 5.69 and 6.11 cm and are with error level of 7.5%. The comparison of these results show that whatever the rate of structure's attenuation is more, the accuracy of approximate method will be more. The comparison of Fig. 5 and 6 show that with decreasing period time of structure the accuracy of this approximate method decreases as well that this case according to stated information in second section is completely logical. Now for doing this comparison in

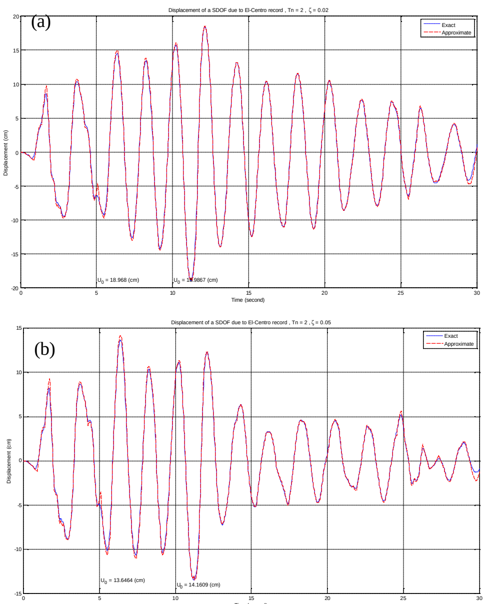

Fig. 5: The response of time history of single freedom degree structure with period time of 2 sec and attenuation; a) 2% and b) 5%

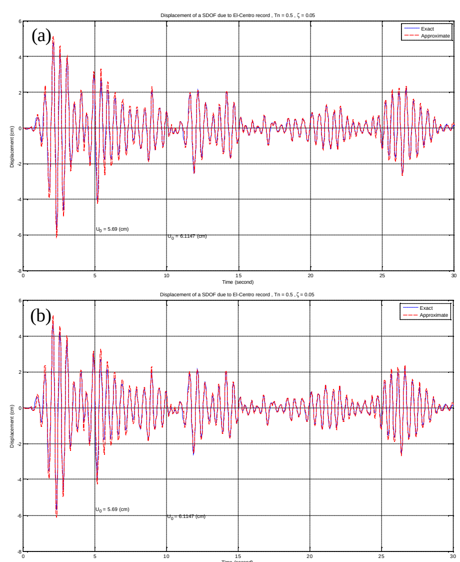

Fig. 6: The response of time history of single freedom degree structure with period time of 0.5 sec and attenuation; a) 2% and b) 5%

various periods time, in Fig. 7 respond spectrum obtained from two accurate and approximate methods for attenuation of 2% and in Fig. 8 respond spectrum for attenuation of 5% is drawn. With comparing accurate and approximate spectrums it can be concluded that through

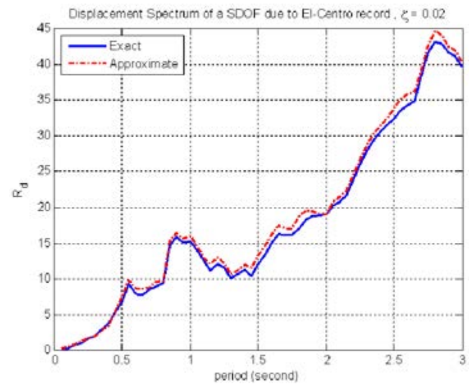

Fig. 7: Displacement spectrum of a SDOF due to el-Centro record with accurate and approximate methods for attenuation of 2%

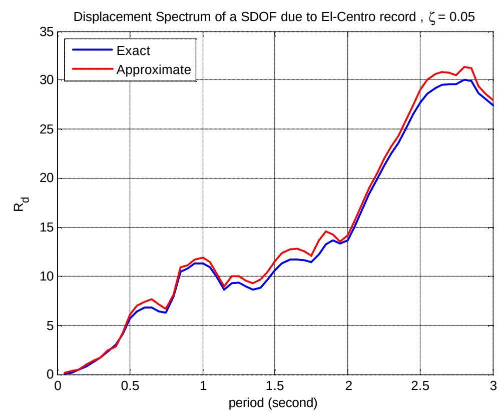

Fig. 8: Displacement spectrum of a SDOF due to el-Centro record with accurate and approximate methods for attenuation of 5%

decreasing period time, the accuracy of period won't necessarily decrease and this case completely depends on type of earthquake record and its equaling way with consequent hits. But according to the results of these two diagrams, it is generally can be said that proposed method despite significant decrease of calculations' volume, the accuracy of analyzing method is significantly decreased.

CONCLUSION

In this study, a method has been proposed to simplify the earthquake's records based on the concept of hit load. For this purpose, earthquake's record was divided to the number of pulses in the range of zero acceleration areas and each pulse was equivalent by a hit load. The numerical results based on the accurate and the approximate method show that this method can reduce 10-15 times of calculations while the error caused by simplification of that can be up to about 10% depending on the period of structures, its attenuation and also the content of earthquake record frequency. This method can even be used as a means of manual approximate of maximum seismic response of structures by having several main peaks of earthquake's record and the area under them.

REFERENCES

Chopra, A.K., 1995. Dynamics of Structures. Prentice Hall, New Jersey, USA.

Costa, J.D., R. Bento, V. Levtchitch and M.P. Nielsen, 2005. Simplified non-linear time-history analysis based on the theory of plasticity. WIT. Trans. Built Environ., 81: 1-11.

Oskoei, S.A.G. and G. McClure, 2009. Simplified dynamic analysis methods for guyed telecommunication masts under seismic excitation. Proc. Struct. Congr., 2009: 1-10.

Soroushian, A., 2008. A technique for time integration analysis with steps larger than the excitation steps. Commun. Numer. Methods Eng. Spec. Issue, 24: 2087-2111.

Wang, W.Y.L., 1975. Structural instability during earthquakes and accelerogram simplification. Ph.D Thesis, Michigan University, Ann Arbor, USA.