

Computer Programs Using for Nonlinear Response of Multi-Story Shear Buildings Under Lateral Dynamic Loads and Earthquakes Loads Using Wilson- θ Method

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ABSTRACT

Engineering structures may behave nonlinearly under moderate to high level earthquakes where an effective nonlinear method of effective dynamic analysis is to be needed. The Wilson- θ method is an implicit solution which is a step-by-step unconditionally stable method. The method serves to assure the numerical stability of the solution process regardless of the magnitude selected for the time step.

The change in material properties of the system during vibration is considered in this work in the stiffness and damping to present any form of nonlinearity in the system. The changes in damping and stiffness are evaluated at the initiation of each time increment and assumed to remain constant during the time interval. The structural response in the form of displacement, velocity, and acceleration are computed at each time step. The displacement and velocity are calculated at the end of each time interval and considered as the initial conditions for the next time step.

Two computer programs are present in this work for the nonlinear method of seismic analysis of multi-story shear buildings. Under lateral and base excitations. The details of the computer programs written for the lateral and earthquake loading and used for calculating the dynamic response of structures in terms of displacement, velocity, and acceleration for linear and nonlinear single and multi-story shear buildings are given in this work with two block diagrams.

It is important to note that the programs deal with elastic linear behavior and nonlinear in the form of elastoplastic behavior.

Keywords: Nonlinear system, elastic and elastoplastic behavior, lateral and earthquake loading.

المخلص

الهندسة الإنشائية لها تأثير غير خطي تحت مستوى زلزالي متوسط إلى عالي للزلازل التي تؤثر بطريقة غير خطية على التحليل الديناميكي.

طريقة (Wilson-θ) هي طريقة الحل بطريقة الخطوة بخطوة غير المشروطة للتحليل الديناميكي. هذه الطريقة تختلف اختلافاً جوهرياً عن طريقة التحليل المستقر باستخدام أي مقدار للوقت في كل خطوة. فالتغير في خصائص المواد خلال الاهتزاز من حيث الصلادة والإخماد من خصائص النظام غير الخطي. والتغيرات التي تحدث في الصلادة والإخماد تبقى ثابتة خلال الفترة الزمنية، عند حساب الإزاحة والسرعة عند كل نهاية فترة زمنية تعتبر شرط مبدئي للخطوة التي تليها.

تم استخدام برامج الحاسب الآلي لحساب المعادلات غير الخطية وخاصة في التحليل الديناميكي للمباني المتعددة الطوابق تحت شروط مقيدة. فبرامج الحاسب تستخدم لحساب الاستجابة الديناميكية التي تمثل الإزاحة والسرعة والعجلة تحت تأثير القوة الجانبية وقوة الزلازل للنظام الخطي وغير الخطي للمباني ذات طابق واحد ومتعددة الطوابق.

من أهمية هذه البرامج أنها تستخدم النظام الخطي المرن والنظام غير الخطي وغير المرن.

الكلمات المفتاحية: النظام غير الخطي، السلوك المرن وغير المرن، القوة الجانبية وقوة الزلازل.

1. Introduction

Earthquakes are any sudden disturbance within the earth manifested at the surface by a shaking of the ground. This

shaking, which accounts for the destructiveness of an earthquake, is caused by the passage of elastic waves through the earth's rocks. These seismic waves are produced when some form of stored energy, such as elastic strain, kinetic energy, chemical energy, or gravitational energy, is released suddenly. And to study an earthquake's destructiveness depends on many factors, these factors include the focal depth, the distance from the epicenter, and the design of buildings. The extent of damage also depends on the density of population and construction in the area shaken by the quake.

There are many important classes of structural dynamic problems which cannot be assumed to be linear. The response of a building to a seismic load severe enough to induce inelastic deformations makes the building behavior nonlinear. Linear behavior is always elastic while nonlinear material behavior may be elastic or inelastic.

The Wilson- θ method is the step- by- step unconditionally stable method which is used for this aspect of nonlinear dynamic analysis. [1] [2] [3] [4]

This study is extended paper of the previous referred as reference (1), and in that work will present the details of the computer programs which used for nonlinear system under earthquake loads. In addition, under lateral loads using by unconditionally Wilson- θ method. And to use computer system programs (Linear and nonlinear programs) to solve dynamic analysis.

2. Computer Programs

The computer programs written in Quick-BASIC using for the linear and nonlinear single-story and multi-story shear buildings dynamic analysis. The change in material properties of the system during vibration is in the stiffness and damping to present any form of nonlinearity in the system.

The damping and stiffness are evaluated at the initiation of each time increment and assumed to remain constant during the

time interval. The displacement, velocity, and acceleration are computed at each time step. The displacement and velocity are calculated at the end of the time interval and considered as the initial conditions for the next time step. To focus on the damping vibration (damping coefficient).

The system stiffness matrix, $[K]$, the system mass matrix, $[M]$, and the system damping matrix, $[C]$, are represented in the computer program by the two dimensional arrays SK(I , J), SM(I , J), and SC(I , J) respectively.

The number of degrees of freedom, N , is represented by ND. Wilson- θ factor is given in the program by THETA. The user can use DT to refer to time step of integration, Δt . The maximum time of integration to be specified by the user is given by TMAX. Force against time data points in the program are given by P(I) and TC(I). NEQ is chosen for specifying the number of data points to be used to represent the excitation with time. For the elastoplastic cases, the maximum force in tension and in compression are given by RT and RC respectively.

The programs can perform a linear interpolation process between the input excitation data points for the specified input time incremental points. The program results in the magnitude of the applied forces at each nodal coordinate calculated at increments of time equal to the time step Δt . Each program calculates the initial acceleration and the response for each nodal coordinate in terms of displacement, velocity, and acceleration at increments of time Δt up to the maximum time specified, TMAX.

The steps of the first program used for lateral dynamic loads a block diagram is employed and shown in Figure 1, and the steps of the second program used for earthquake loads are given in a block diagram employed and shown in Figure 2.

The steps are self-explanatory as they are given in details with the necessary equations or formulas. To study the phenome of earthquake to reduce by using linear and nonlinear programming. To study the block diagram by using Equations

(dynamic load).

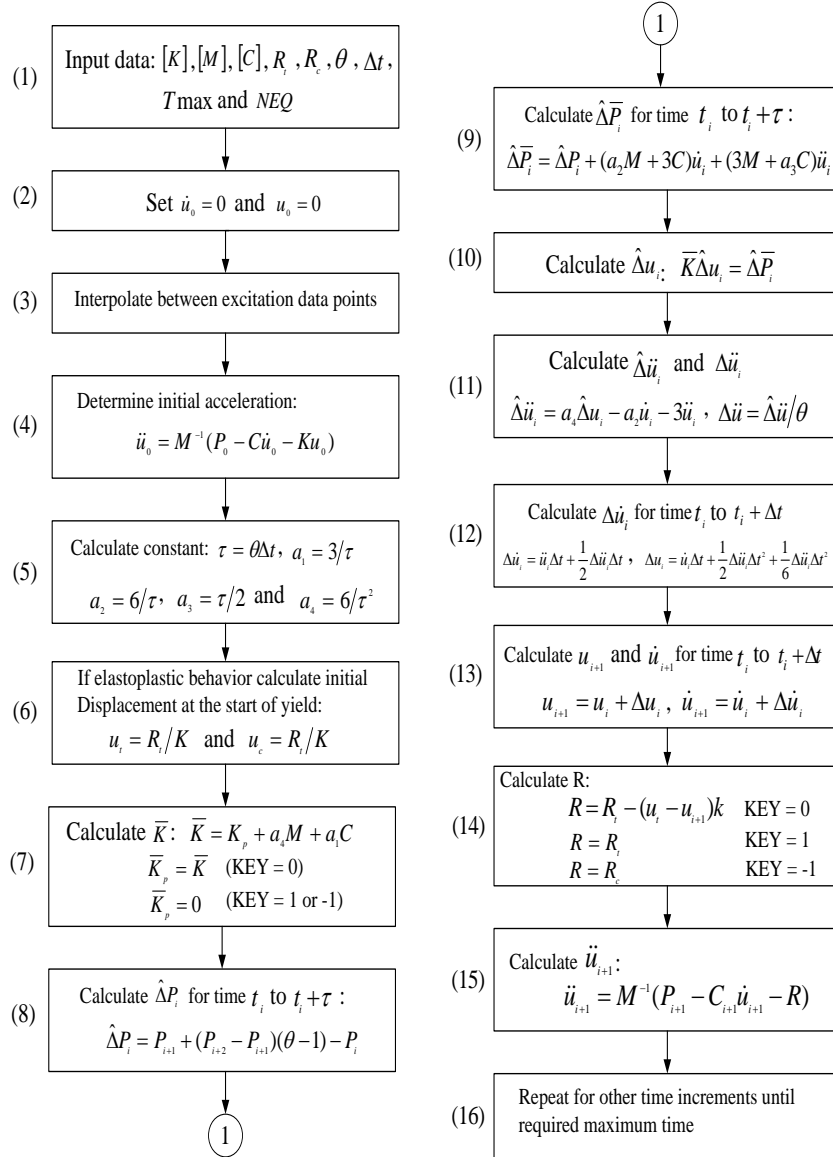


Figure 1. Block diagram for the computer program used for lateral dynamic loads using Wilson-θ method.

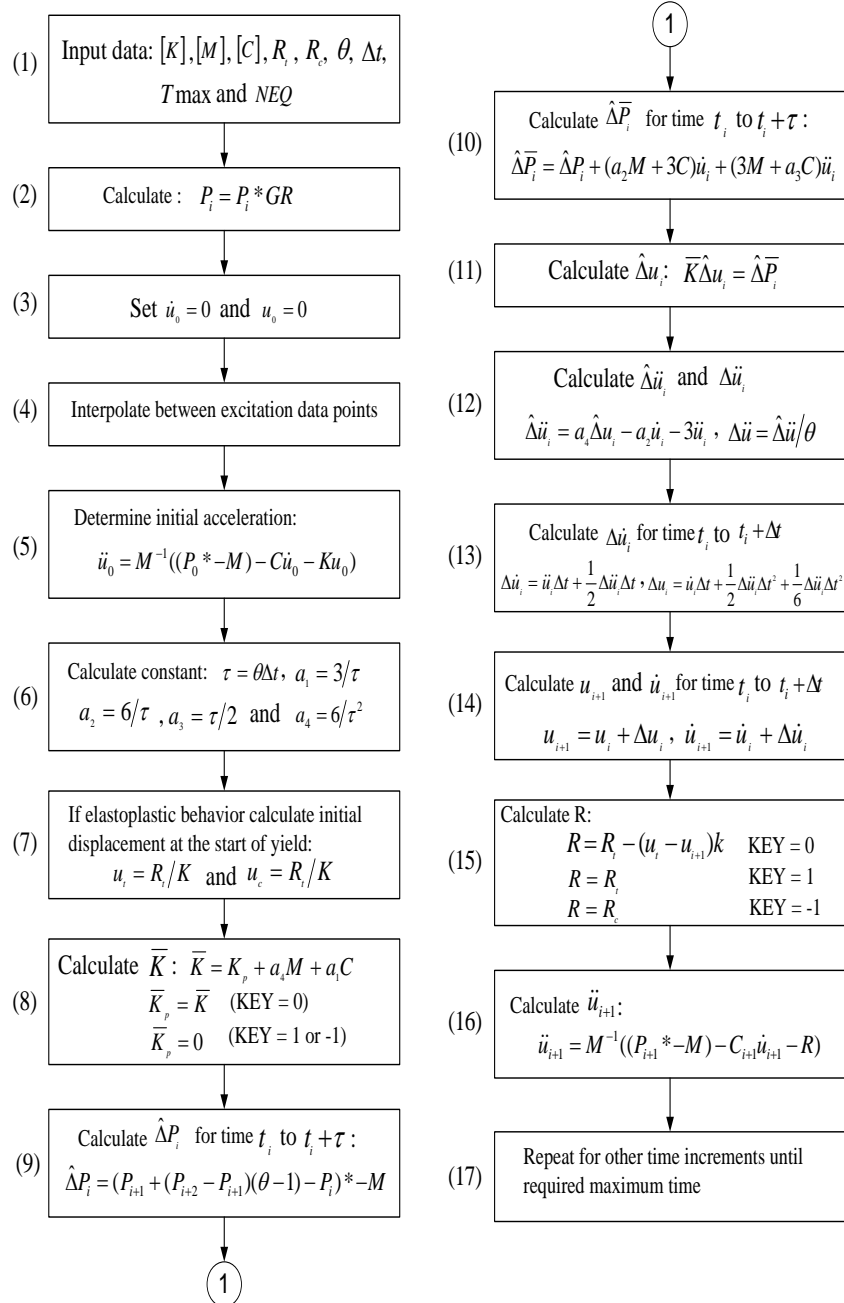


Figure 2. Block diagram for the computer program used for earthquake loads using Wilson- θ method.

3. Computer Programs Applications

The Computer programs are employed in the following two applications:

3.1. Application 1: Elastic Multi Degree of Freedom System Under Lateral Load

The analysis of a two-story shear building system shown in Figure 3. It is subjected to a suddenly Lateral force of $10kips$ at the level of the second floor for the whole time used for the analysis [4].

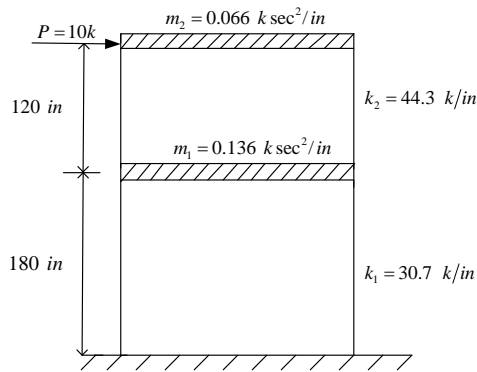


Figure 3. Two-story shear building under a constant Lateral load of $10kips$.

3.2. Application 2: Elastoplastic Multi Degree of Freedom System Under Constant Base-Acceleration

In this application a two-story shear building system shown in Figure 4, with elastoplastic behavior. It is subjected to a constant acceleration of $0.28g$ applied suddenly at the foundation, where g is the gravitational acceleration ($g = 386in/sec^2$).

The plastic moment for the columns on the first or second story is $M_p = 154.942kip.in$. [4]

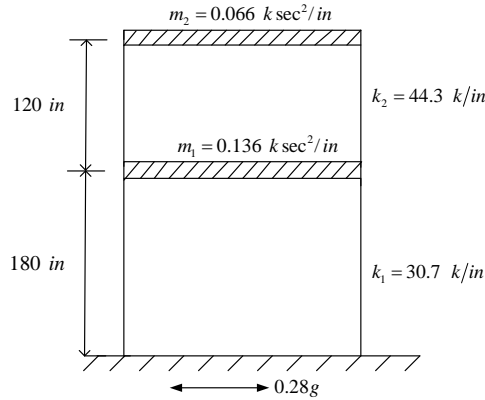
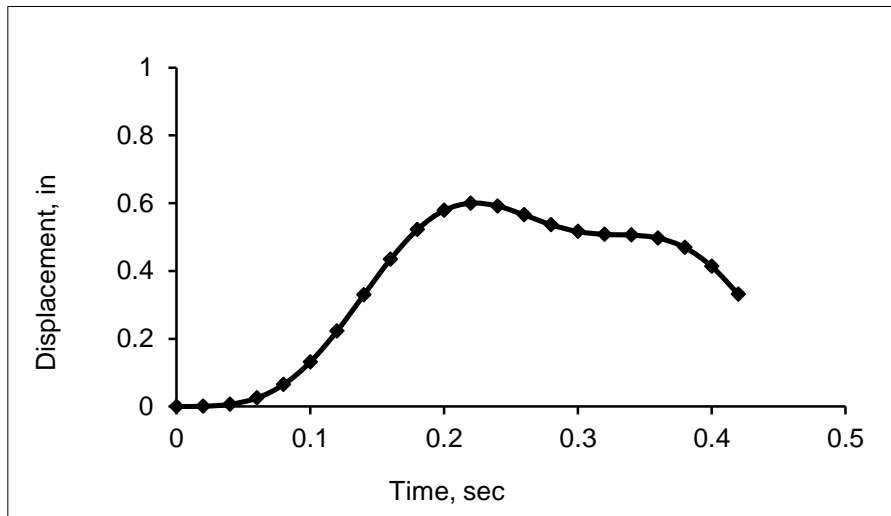


Figure 4. Two-story shear building under a constant acceleration of $0.28g$.

The applications were solved by the computer programs by using Wilson- θ method. The results for application (1), displacement, velocity, and acceleration are plotted in Figure 5 for story 1 and Figure 6 for story 2. And for application (2) are plotted in Figures 7 and 8 for story 1 and 2 respectively.



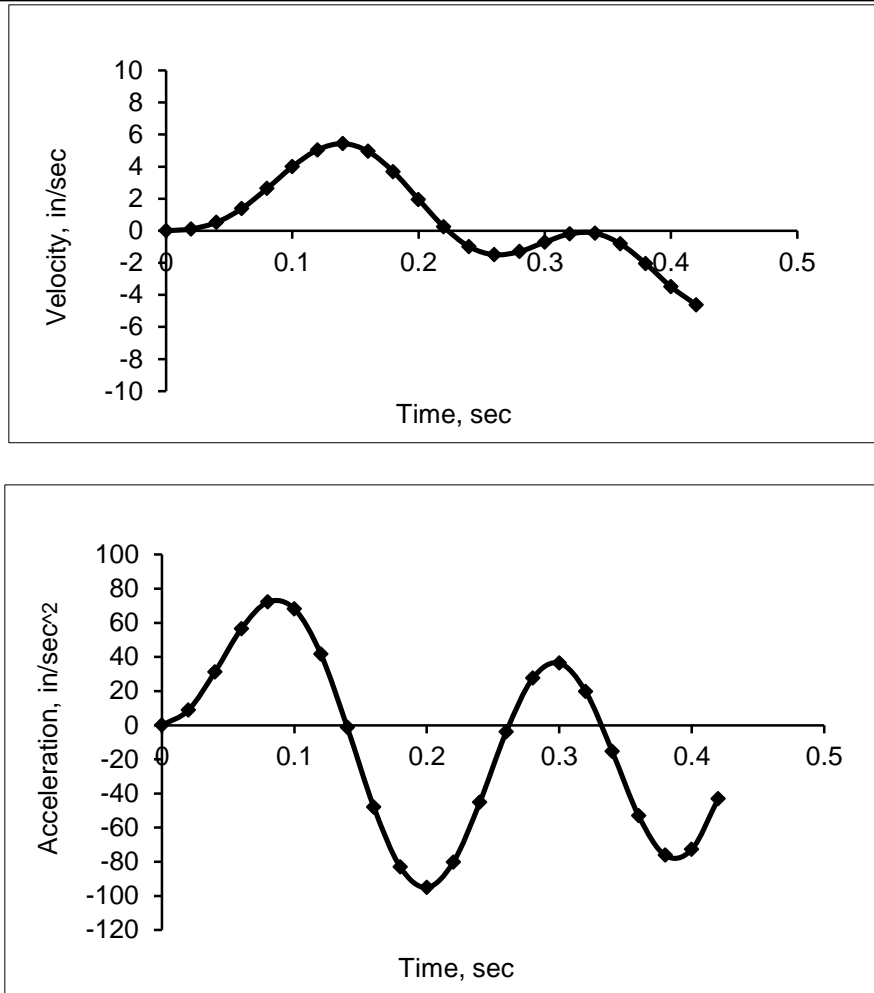


Figure 5. Response for application (1), elastic behavior for Story 1.

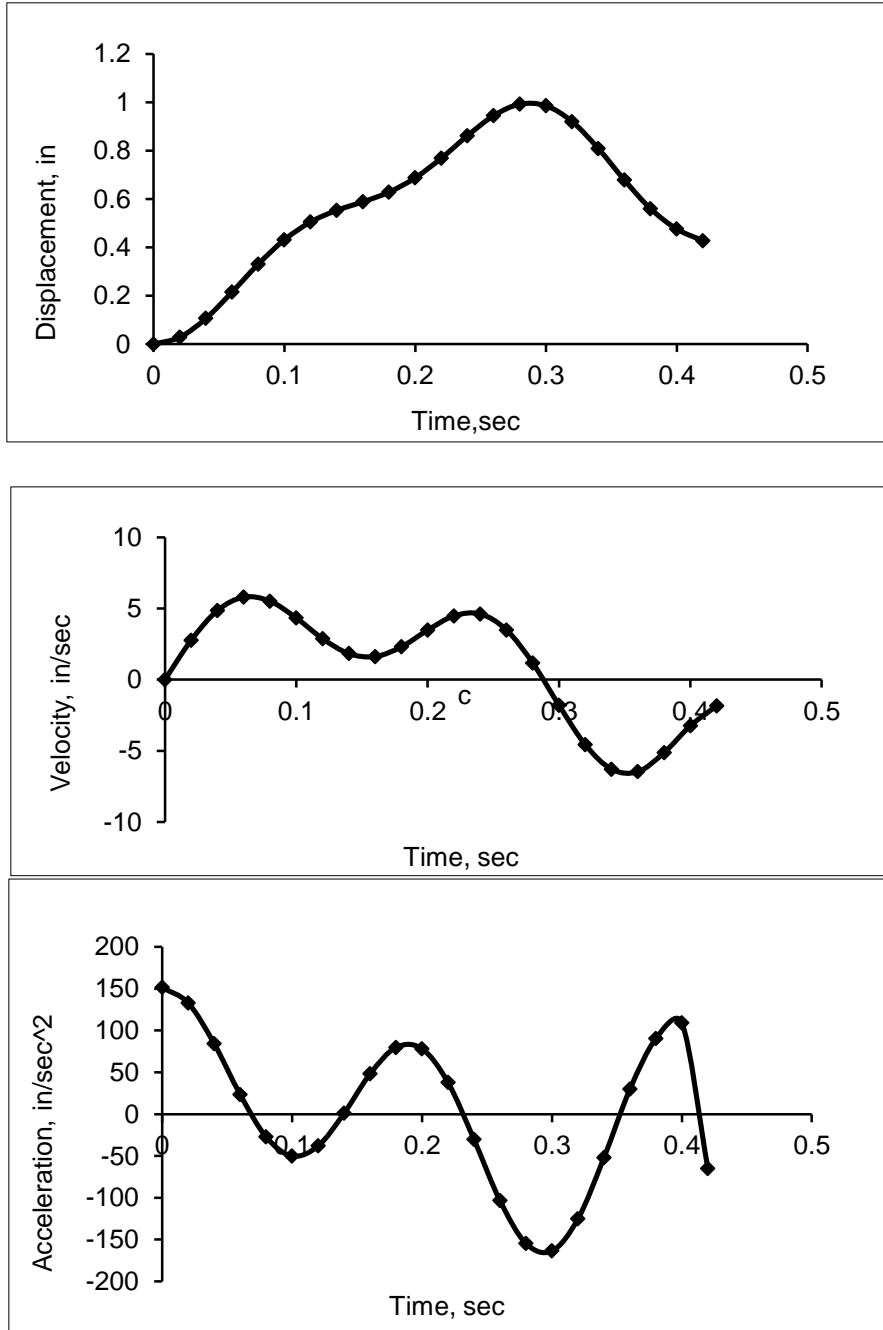


Figure 6. Response for application (1), elastic behavior for Story 2.

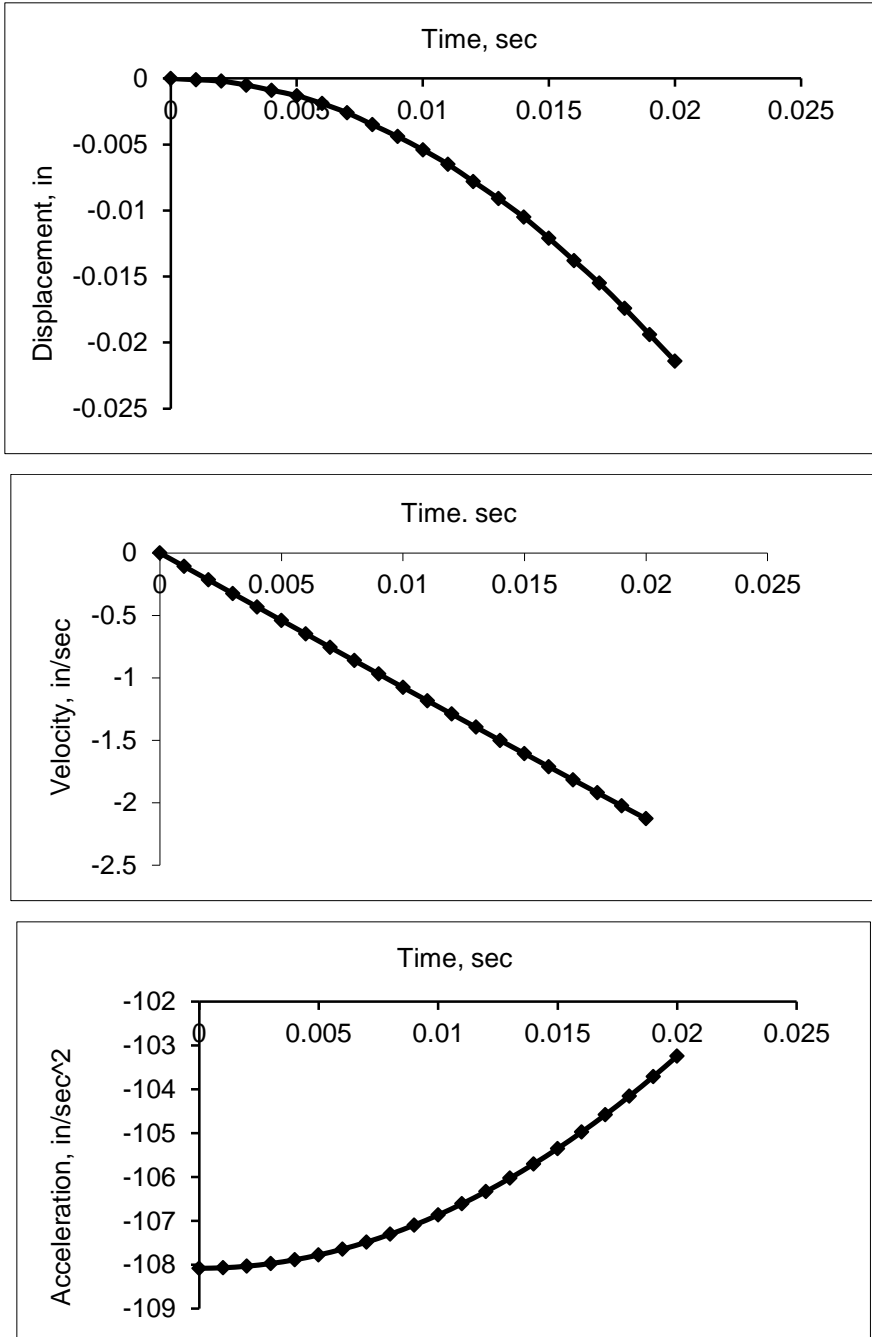


Figure 7. Response for application (2), elastoplastic behavior for Story 1.

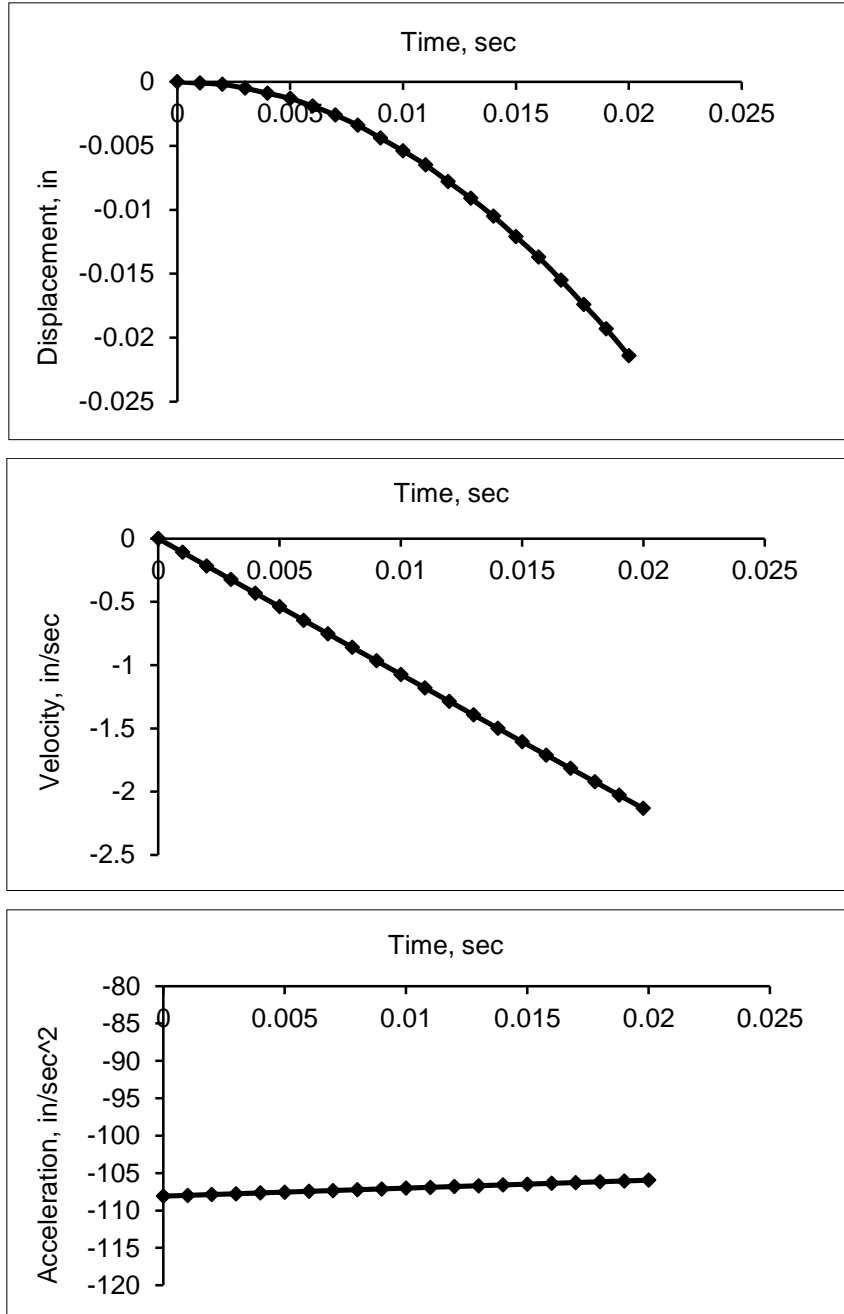


Figure 8. Response for application (2), elastoplastic behavior for Story 2.

5. Conclusion:

In the present work, two computer programming used for linear and nonlinear response of single or multi-degree of freedom shear buildings under lateral dynamic loads and earthquakes loads, And the programs can be used for the analysis of dynamic system with elastic behavior or elastoplastic behavior, two computer programs were written in Quick-BASIC language.

The Wilson θ method is the step- by- step unconditionally stable method to be used for this aspect of nonlinear dynamic analysis. Change in material properties of the system during vibration was in the stiffness and damping to present any form of material nonlinearity in the system.

References:

- [1] A. O. Twil, "Nonlinear Structural Dynamic Response of Multi-Story Buildings Under Seismic Loading," *First Conference for Engineering Sciences and Technology*, vol. 4, pp. 482-493, 25-27 September 2018. <http://cest2018.elmergib.edu.ly/>
- [2] Anil K. Chopra, "Dynamics of Structures ", Second Edition, Pearson Education, 2003.
- [3] Ray W. Clough and Joseph Penzien "Dynamic of Structures ", Computers and Structures, Second Edition, 2003.
- [4] Mario Paz, "Structural Dynamics ", Van Nostrand Reinhold Environmental Engineering Series, 1985.
- [5] Norman B. Green, "Earthquake Resistant Building and Construction", Litton Educational Publishing, 1978