©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya/Antalya - Turkey)

Nonlinear analyzing of RC frame buildings subjected to earthquake

Moussa Twizere, *Naci Caglar, Hakan Ozturk
Faculty of Engineering, Department of Civil Engineering, Sakarya University, Sakarya, Turkey

Abstract

During the earthquake reinforced concrete (RC) beams or columns may fail and fail of some RC columns may lead to collapse of entire buildings. RC buildings should be well designed in order to minimize the damage of buildings and loss of life. In this study, a new developed code was verified with the results of SAP2000 and then the code was applied to determine the response of selected real RC buildings located in Bingol seismic zone. The response of buildings was shown as schematic diagram of the plastic hinge locations.

Key words: reinforced concrete frame building, time history analysis, moment-curvature, plastic hinge

1. Introduction

Turkey is located on one of the most active earthquake zone which has earthquake periods quite often with shortest return periods. During the last century, more than twelve major earthquakes with minimum magnitudes 7 (Mw) caused significant casualties, severe damages to a lot of structures and lifelines in Turkey [1].

Most of RC buildings were designed and constructed before current Turkish Seismic Code requirements. They cannot provide the required ductility, lateral stiffness and strength in accordance with current Turkish Seismic Earthquake Code requirements [2]. Reinforced concrete (RC) buildings are consisting of structural elements such as beams and columns connected to each other. RC buildings should be well designed in order to minimize the damage of buildings and loss of life. During the earthquake RC beams or columns may fail and fail of some RC columns may lead to collapse of entire buildings.

Time history analysis is one of the ways to determine the response of RC buildings subjected to earthquake. This method is more effective than the other methods in order to determine realistic response of RC buildings [3-6]. The response of any kind of buildings can be determined by using nonlinear time history analysis [7].

The main objective of this paper is to determine the earthquake response of selected real RC buildings by using of TWIZ code. The code was developed by using of the Matlab program [8]. In this study, it is studied the formation of a plastic hinge at the ends of all structural elements corresponding to its moment capacity and its effect to response of RC buildings. A schematic diagram of the plastic hinge locations of RC frame buildings are shown for earthquake time steps.

*Corresponding author: Address: Faculty of Engineering, Department of Civil Engineering, Sakarya University, 54187, Sakarya, TURKEY. E-mail addresses: caglar@sakarya.edu.tr

In the end of the paper, the results of the developed code were compared to response of selected real RC buildings subjected to 2003 Bingol Earthquake.

2. TWIZ Code

TWIZ code has been developed to investigate the response of RC frame buildings. This code uses combination of methods such as finite element method, stiffness method and nonlinear time history method. The global stiffness matrix and global mass matrix of frame was taken into account. XTRACT program was used to calculate the relationship of moment-curvature for RC beams and columns [9]. In this code, the plastic hinges are assumed to form at ends of the structural elements which are reached to its moment capacity determined by moment-curvature analysis.

The first step in the code is to define the structure material properties and the coordinate of structure in X, and Z directions then to define the beams and columns sections and considering boundary conditions. By defining the data, the code determines the global mass matrix and global stiffness matrix. It uses lumped mass matrix to evaluate every element mass matrix.

The idealized frame-1 (Fig. 1) subjected to Kocaeli Earthquake was used to verify the developed code. The results of the developed code were compared with the results of SAP2000 program. This frame has two spans and three stories with heights of 4m. The section of beams and columns were selected as 400x400mm.

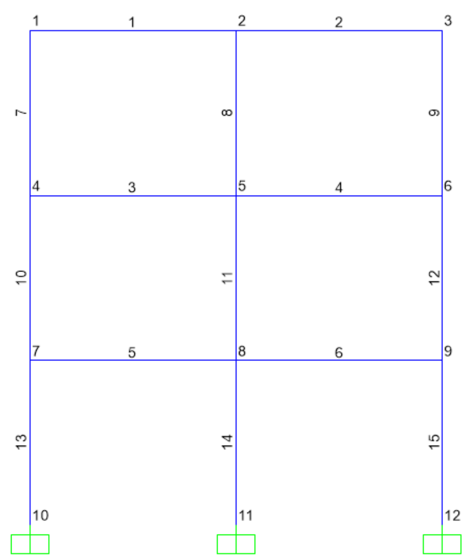


Figure 1. Idealized frame for confirming the developed Code

The periods of first 5 modes and bending moments at time step 9.98 sec for the idealized RC buildings are tabulated in Table 1 and Table 2 respectively.

Table 1 Comparison of the results of TWIZ Code and SAP2000

Mode	Periods (sec)		Error (%)
	TWIZ Code	SAP2000	
1	0.3155	0.3190	1.10
2	0.1011	0.1023	1.22
3	0.0607	0.0615	1.39
4	0.0236	0.0235	0.14
5	0.0197	0.0197	0.17

Table 2 Bending moment results at selected time step (t=9.98 sec).

Frame	Joint	Bending Moment (kNm)		Error (%)
		TWIZ Code	SAP2000	
1	1	20.26	20.63	1.62
1	2	17.04	17.23	1.07
2	2	16.85	17.23	2.15
2	3	20.15	20.63	2.29
3	4	44.64	45.31	1.45
3	5	40.25	40.72	1.14
4	5	40.07	40.72	1.58
4	6	44.48	45.31	1.81
5	7	60.01	60.92	1.48
5	8	52.24	52.88	1.20
6	8	52.13	52.88	1.40
6	9	59.92	60.92	1.62
7	1	20.29	20.63	1.61
7	4	9.71	9.70	0.04
8	2	-33.90	-34.45	1.58
8	5	24.74	25.01	1.07
9	3	-20.15	-20.63	2.29
9	6	9.60	9.70	1.00
10	4	34.94	35.61	1.86
10	7	27.24	27.70	1.63
11	5	55.58	56.42	1.47
11	8	52.11	52.82	1.32
12	6	34.88	35.61	2.03
12	9	27.19	27.7	1.84
13	7	32.70	33.22	1.34
13	10	61.24	62.65	2.24
14	8	52.26	52.95	1.29
14	11	71.01	72.33	1.81
15	9	32.73	33.22	1.45
15	12	61.22	62.65	2.26

The results of displacement in x-direction and z-direction are illustrated in Figures 2 and 3 respectively while the results of rotation at joint 1 are shown in Figures 4. As can be seen in Figures 3 to 5 the code can determine correctly the response of RC buildings with linear time history analysis by corresponding the results of SAP2000 program.

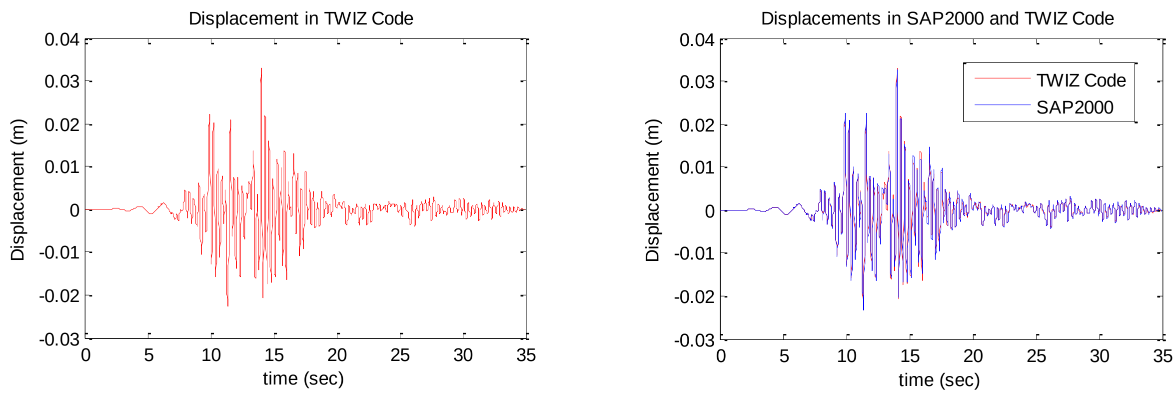


Figure 2.The displacement time histories in x-direction

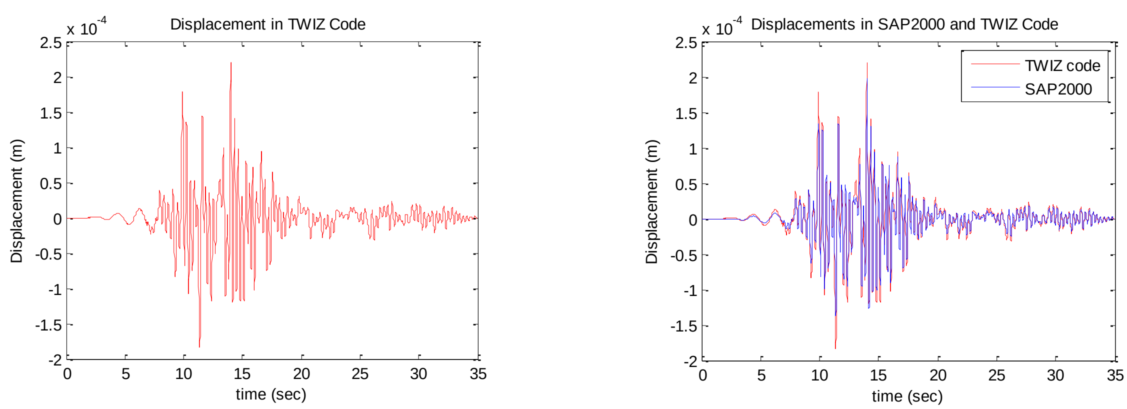


Figure 3.The displacement time histories in z-direction

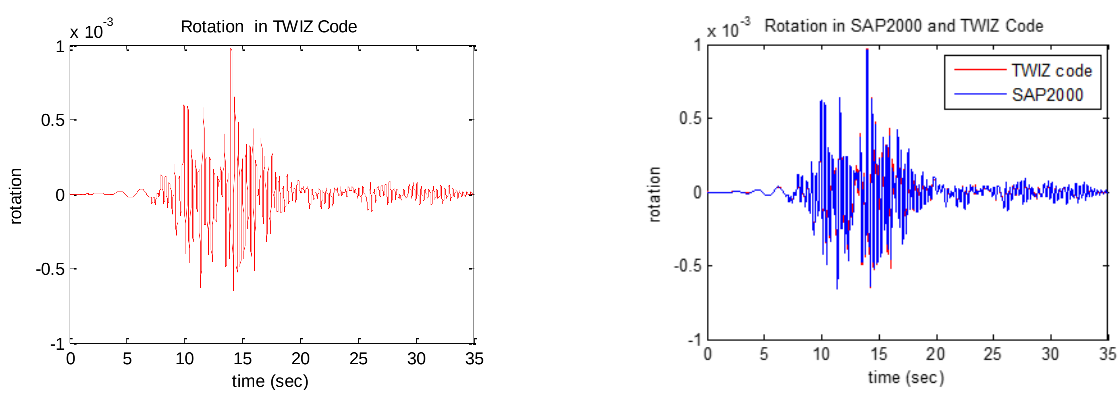
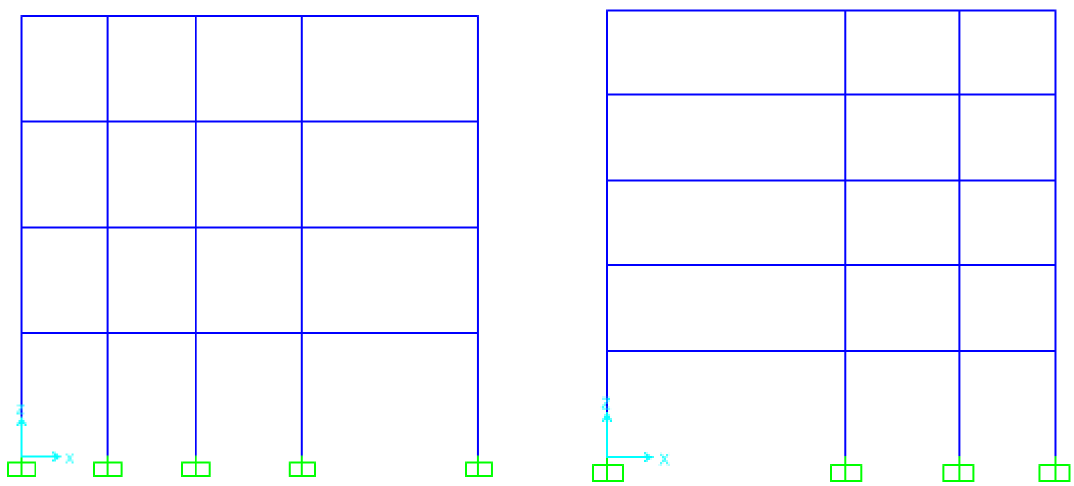


Figure 4.The rotation time histories in y-direction

3. Numerical Study

Two different RC frame buildings, Structure-1 and Structure-2, which are gathered from real buildings response in literature [10] were analyzed with the TWIZ Code. The first one collapsed and the other one didn't get any damage during the 2003 Bingol Earthquake.

Structure-1 has four spans with four stories. The height of ground floor is 3.50m and others are 3.0m in the Structure-1. The building has different columns sections and same beam sections with 250mm/400mm. Structure-2 has three spans with five stories. The height of ground floor is 3.80m and others are 3.0m in the Structure-2. The building has different columns sections and same beam sections with 250mm/400mm (Figure 5). The cylinder compressive strength of concrete is 16 MPa and yield strength of reinforcement steel is 420MPa in these two buildings. The details of buildings can be find in the literature [10].

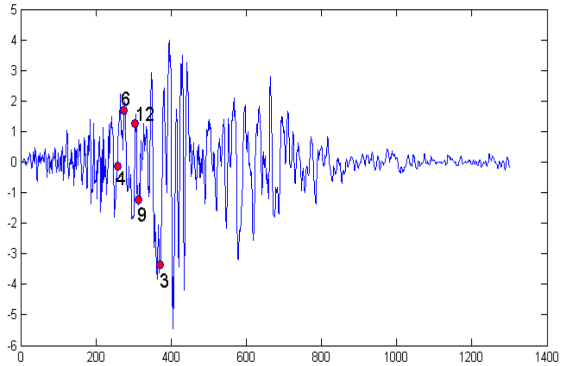


Structure-1 Structure-2

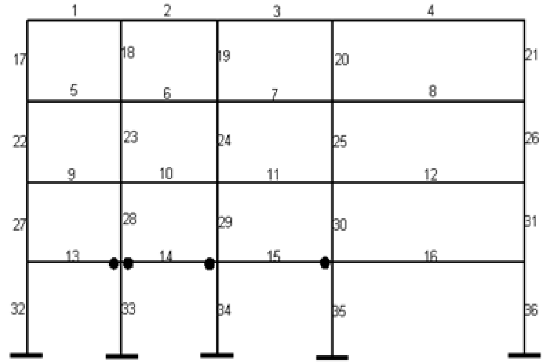
Figure 5. Structure frames which gathered from literature [8]

4. Results and Discussion

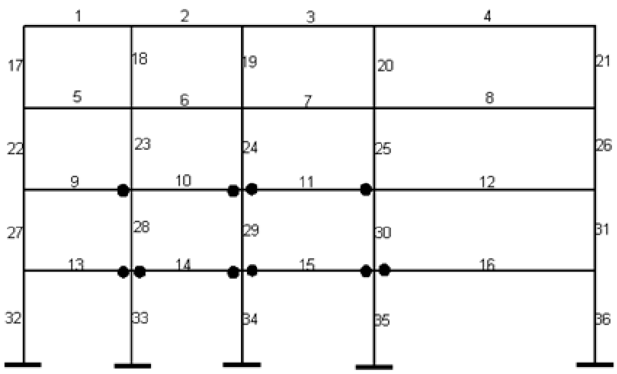
Structure-1 and Structure-2 were analyzed with the TWIZ code and the formation of plastic hinges of these buildings were shown in Figure 6 and Figure 7 respectively for time steps.



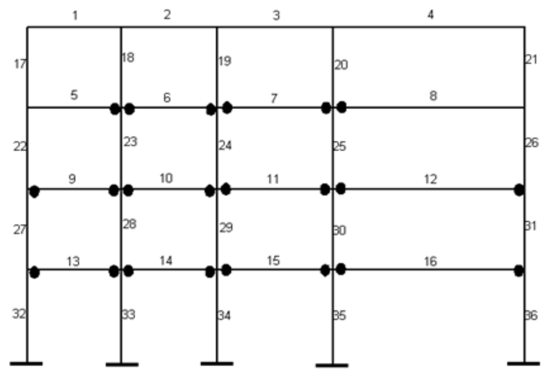
Number of plastic hinges formed



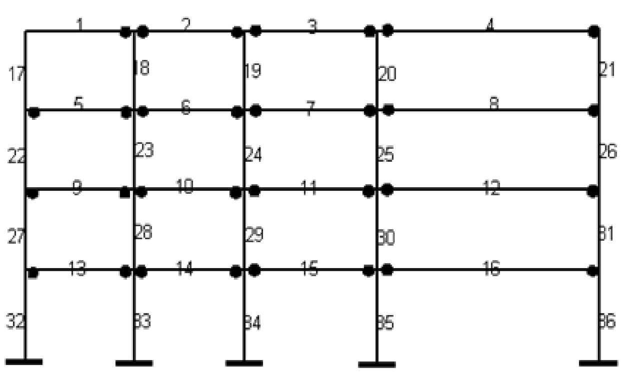
Formation of first 4 Plastic hinges



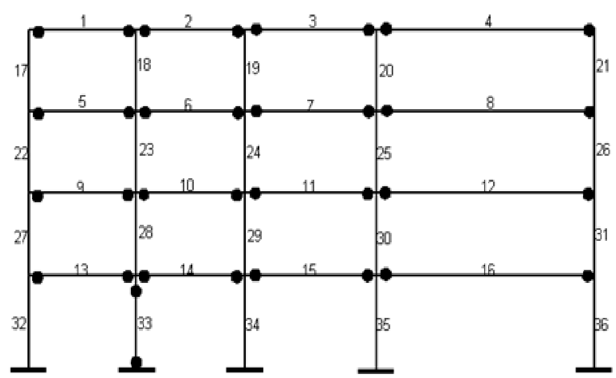
Formation of 10 plastic hinge



Formation of 22plastic hinge

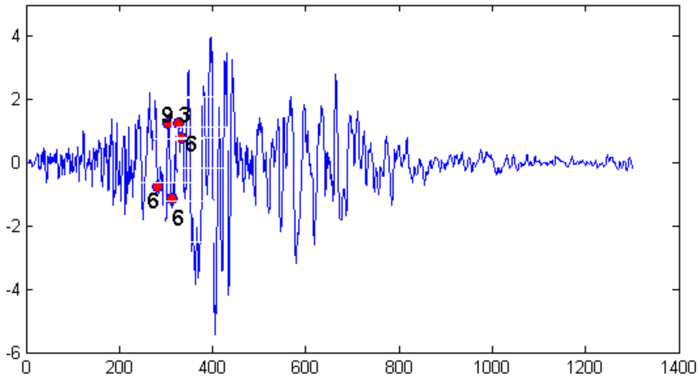


Formation of 31 plastic hinge

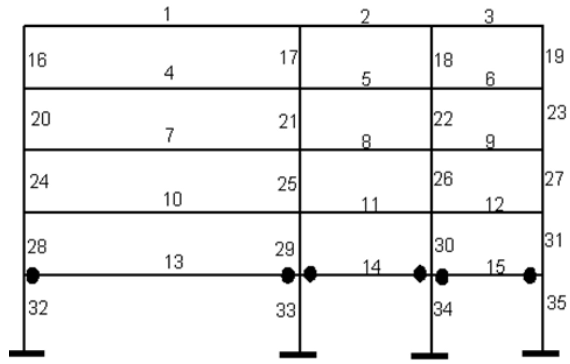


Formation of 34 plastic hinge

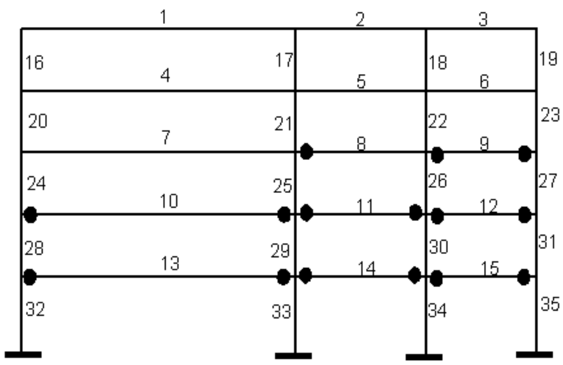
Figure 6. Formation of plastic hinge results for Structure-1



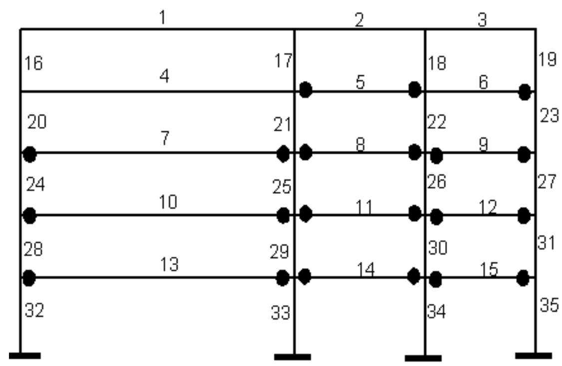
Number of plastic hinges formed



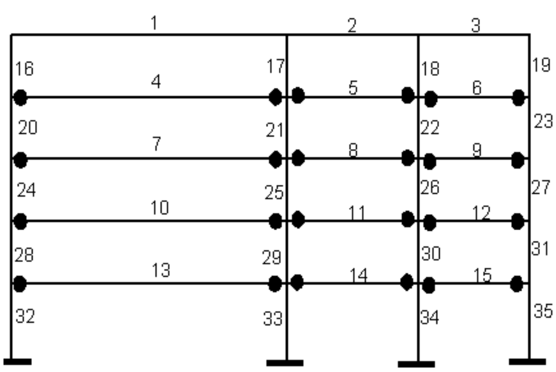
Formation of first 6 Plastic hinges



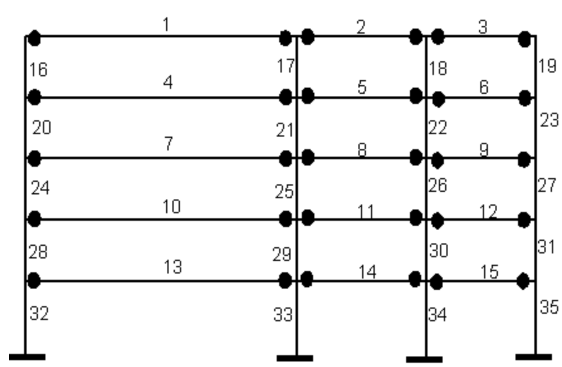
Formation of 15 plastic hinges



Formation of 21 plastic hinges



Formation of 24plastic hinges



Formation of 30 plastic hinges

Figure 7. Formation of plastic hinge results for Structure-2

4. Conclusion

In this paper, the response of RC frame buildings subjected to 2003 Bingol Earthquake were determined by using of developed a new code. This code uses finite element method, nonlinear method, stiffness method and time history analysis method. XTRACT program was also used to calculate the moment curvature relationship of beams and columns sections. SAP2000 program was used to verify the code. The bending moments of elements, the displacements and rotations of nodes were determined successfully with small difference as the big difference was 2.29% in bending moments by using of verified the code.

Two real RC buildings located in Bingol seismic zone were analyzed with developed code. The first one collapsed and other one didn't get any damage of these buildings in 2003 Bingol Earthquake. The developed and verified code obtained similar results with the real response of these buildings. The first one subjected to Bingol Earthquake had a formation of plastic hinge until the columns fails which is caused to collapse of the RC frame building. In second building there was formation of plastic hinges but the structure didn't reach the level of failure.

References

[1] Muhammet Ugur Özçelik (2014)'' PERA, RBTE ve DBYBHY2007 yönetmeligi kullanilarak mevcut bina deprem performansilarinin belirlenmesi'', Istanbul technical university.

[2] Turkish Earthquake Code (2007) Specification for buildings to be built in earthquake regions. Ministry of Public Works and Settlement, Government of the Republic of Turkey.

[3] Li, Y.R. (1996). Non-Linear Time History and Pushover Analyses for Seismic Design and Evaluation. Phd thesis, Texas Universty, Austin, TX, ABD

[4] Chopra, A.K. ve Goel, R.K. (2002). A modal pushover analysis procedure for estimating seismic demand for buildings. Earthquake Engineering&Structural Dynamics 31:3, 561-582.

[5] Antoniou, S. ve Pinho, R. (2004). Advantages and limitations of adaptive and non-adaptive force-based pushover procedures. Journal of Earthquake Engineering 8:4, 497-522.

[6] Fahjan, Y.M., Vatansever, S. ve Özdemir, Z. (2011). Ölçeklenmiş Gerçek Deprem Kayıtları ile Yapıların Doğrusal ve Doğrusal Olmayan Dinamik Analizi. 1. Türkiye Deprem Mühendisliği ve Sismoloji Konferansı, 11- 14 Ekim 2011, ODTÜ, Ankara.

[7] Haymarhtay and Sanyu Khaing, Development of Structural Analysis Programmer for Plane Truss, International Journal of Scientific Engineering and Technology Research, ISSN 2319-8885, Vol.03, Issue.10 May-2014, Pages:2228-2232

[8] MATLAB, The MathWorks, Inc., Natick, Massachusetts, United States. Moller, A.F. (1993), "A scaled conjugate gradient algorithm for fast supervised learning", Neural Networks, 6, 525-533.

[9] XTRACT and User Manual, "Cross-sectional X structural analysis of components, Imbsen Software Systems, 9912 Business Park Drive", Suite 130 Sacramento, CA 95827

[10] SERU [Structural Engineering Research Unit], Middle East Technical University, Ankara, Turkey; Archival Material from Bingol Database located at website http://www.seru.metu.edu.tr, May, 2011.