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The Developed FEA-Based Program for Planar Dynamic Analysis with a Special 12x12 Rectangular Element

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Abstract

There are several widely used structural softwares to analyze buildings under dynamic loads, but many of these programs use arithmetic formulations to calculate the mass and stiffness matrices of shear walls with only 8x8 elements that ignore the rotational mass and stiffness values. Also, during the dynamic analysis, a system diagonal mass matrix containing only elements in the x and y directions is used. The previously mentioned calculation assumptions may lead to unrealistic structural calculations besides these assumptions should be replaced by more realistic calculation formulas and methods. In this paper, a two-part FEA computational program was developed to provide actual structural dynamic analysis. The first part of the program is called YAY2020-Static encoded by FORTRAN compiler and the second one is called YAY-Dynamic encoded by MATLAB interpreter. In YAY2020 program, a special rectangular element formula with 12x12 elements and three degrees of freedom at each element's nodes is used to calculate shear wall mass and stiffness matrices to obtain system full-size stiffness and mass matrices that contain both diagonal and non-diagonal elements. Results obtained using YAY2020 software will be compared with some structural analysis techniques such as shear building and wide column, to study the feasibility of using these techniques. All obtained results by YAY2020 will be compared with the commonly use FEA structure software SAP2000.

Key words

Dynamic analysis software, FORTRAN, Finite element analysis (FEA), 12x12 Mass matrix, Shear building, Wide column

1. INTRODUCTION

Turkey is one of the countries which settled in a strong seismic active location due to the presence of many seismic faults. These seismic movements cause significant physical and economic damages to building elements, which leads to catastrophic damage and loss of life. Dynamic loads are the most important factors causing structural collapse. Although many dynamic loads such as wind and blast loads may cause significant damage to buildings, earthquakes effect are the most dangerous dynamic load that structures are exposed to, because earthquakes not only affect a single building such blast loads but also affect a large scale, causing damage to entire cities and to many buildings at the same time.

Öztorun [1, 2] started his works on finite element methods in the structural engineering field, in 2006 presented the first rectangular stress elements with 12×12 matrix elements adding rotational values and the mass matrix with real and full diagonal and non-diagonal values. Wilson [3-7] introduced a set of finite element structural analysis programs which called CAL programs. In 1975 his studies were considered bases for many programs such as SAP2000, SAFE, and ETABS. In these programs, shear-wall stiffness and mass matrices contain only

8□8 elements with no stiffness and mass rotation values. So there is no rotation of the element in the vertical direction. The rotation and stress of the joints are calculated depending on the joint's movement laterally or vertically. Bathe [7, 8] presented the detailed procedure of the finite element in his book "Finite Element Procedures ". This book has been a reference for many researchers in the field. Newmark [9] developed the one-step integration method to solve structural dynamics problems under blast and seismic loads. For 60 years, Newmark's method has been applied in the dynamic analysis of many applications such as structures. Chopra [10] explained the procedures of structural dynamic analysis in his book "Dynamics of Structures: Theory and Applications to Earthquake Engineering", with different methods of calculations. Öztorun and others [11, 12] made dynamic analyses of structural systems using the GP-DYNA computer program developed by Öztorun in his doctoral thesis; stated that current analysis methods may not provide sufficient assurance if vertical earthquake records are used.

During calculating the effect of earthquakes on structures general system mass and stiffness matrices must be calculated. Many literature programs considered the mass matrix as a diagonal matrix, and the mass of each floor is the same in the x and y directions with no rotational mass values. Also in calculating mass and stiffness matrices of shear wall elements, literature programs calculate it as just a matrix with 8x8 elements ignoring the rotational values. In this study, a two-part computational program based on the finite element method will be encoded using the FORTRAN compiler and MATLAB interpreter to find the response of a planar structure with a known geometry under dynamic loads. This program is called YAY2020. In principle, FORTRAN encoded YAY2020-Static software calculates the mass and stiffness matrices for each of the system elements individually and superposing them together to get system general mass and stiffness matrices. Then these matrices will be used in dynamic calculation by YAY2020-Dynamic. The system mass and stiffness matrices computed in this study contain both diagonal and non-diagonal elements as well as 12x12 elements of shear walls mass and stiffness matrices. To achieve this special formulation is used to calculate the rotational degrees of the plate elements. This formula is developed by Öztorun [1-2], and the accuracy of this formulation had been proven and demonstrated by comparing it with Timoshenko and Goodier [2, 13] analytical solution. All results obtained by YAY2020 will be compared with widely used FEA software such as SAP2000. In light of these features, this study aims to present a program that has different and more realistic calculation methods than the existing ones.

2. MATERIALS AND METHODS

In this section, the YAY2020-Static and YAY2020-Dynamic mechanisms are introduced with an overview of used mathematical formulas.

2.1. Frame Elements Mass Matrix

The frame element is shown in Figure 1. The element has two nodes (i and j) with three degrees of freedom at each end. The axis across from I to J is called the local x-axis and the perpendicular on the local x-axis is called the local y-axis these two axes formed the local coordinate system of the planar frame element.

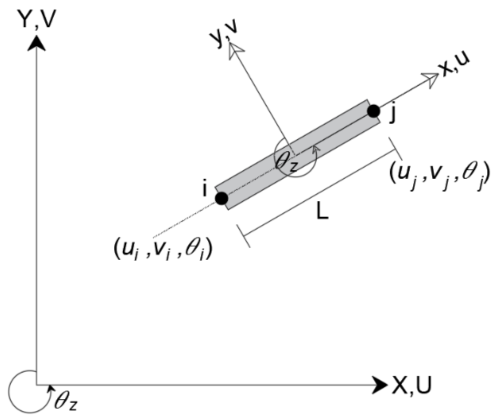

Figure 1. Planar frame element

The element length L is calculated as Eq.1.

$$L = \sqrt{\left(X_j - X_i\right)^2 + \left(Y_j - Y_i\right)^2} \tag{1}$$

Frame element local mass matrix is written as Eq.2. [3, 8]

$$M_{e.l.}^{Frame} = WA\frac{1}{420}\begin{bmatrix} 140 & 0 & 0 & 70 & 0 & 0 \\ & 156 & 22L & 0 & 54 & -13L \\ & & 4L^2 & 0 & 13L & -3L^2 \\ & & & 140 & 0 & 0 \\ & symmetrical & & & 156 & -22L \\ & & & & & 4L^2 \end{bmatrix} \quad (2)$$

Where,

A = cross-sectional area and W = mass density

The mass matrix in Eq.2 is obtained for the local coordinates of the element. To transfer it to a global structure coordinate system a transformation matrix must be used. The planar transformation matrix is given in Eq.3. [3, 8]

$$R = \begin{bmatrix} Cos(\theta) & Sin(\theta) & 0 & 0 & 0 & 0 \\ -Sin(\theta) & Cos(\theta) & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & Cos(\theta) & Sin(\theta) & 0 \\ 0 & 0 & 0 & -Sin(\theta) & Cos(\theta) & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

Here;

$$Cos(\theta) = \frac{X_j - X_i}{L} \quad (4)$$

$$Sin(\theta) = \frac{Y_j - Y_i}{L} \quad (5)$$

The global frame element mass matrix is obtained by multiplying the transpose of the transformation matrix by the local mass matrix and then multiplies the result by the transformation matrix itself, as given in Eq.6.

$$M_{e.g.}^{frame} = [R^T].\left[M_{e.l.}^{frame}\right].[R] \quad (6)$$

Here,

$M_{e.g.}^{\mathrm{frame}}$: Frame element global mass matrix.

R^T: Transposition of the transformation matrix.

$M_{e.l.}^{\mathrm{frame}}$: Frame element local mass matrix.

2.2. Shear Wall Elements Mass Matrix

The shear wall element is analyzed as a rectangular stress element. A special formulation presented by Öztorun is used to analyze rectangular stress elements in YAY2020 program. Figure 2 shows the plane stress rectangular element with four nodes and three degrees of freedom at each node (1 rotation and 2 displacements). The plane stress element mass matrix is given in Table 1.

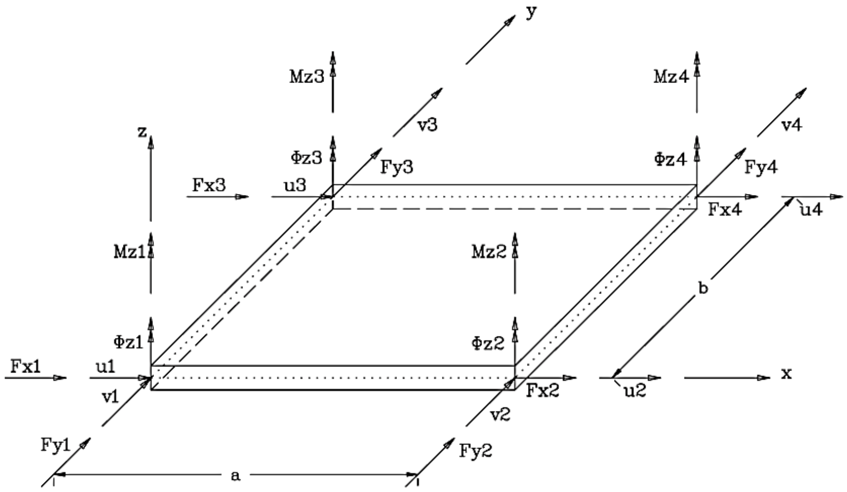

Figure 2. Generalized forces and displacements for finite plate elements for plane stress problems [1]

Table 1. Stiffness matrix of plane stress element [1]

Δ^T	Δ_{X1}	Δ_{Y1}	θ_{Z1}	Δ_{X2}	Δ_{Y2}	θ_{Z2}	Δ_{X3}	Δ_{Y3}	θ_{Z3}	Δ_{X4}	Δ_{Y4}	θ_{Z4}
I/J	1	2	3	4	5	6	7	8	9	10	11	12
1	$M_{S_{1,1}}$	0	$M_{S_{1,3}}$	$M_{S_{1,4}}$	0	$M_{S_{1,6}}$	$M_{S_{1,7}}$	0	$M_{S_{1,9}}$	$M_{S_{1,10}}$	0	$M_{S_{1,12}}$
2		$M_{S_{1,1}}$	$M_{S_{2,3}}$	0	$M_{S_{1,7}}$	$M_{S_{2,6}}$	0	$M_{S_{1,4}}$	$M_{S_{2,9}}$	0	$M_{S_{1,10}}$	$M_{S_{2,12}}$
3			$M_{S_{3,3}}$	$M_{S_{1,6}}$	$-M_{S_{2,6}}$	$M_{S_{3,6}}$	$-M_{S_{1,9}}$	$M_{S_{2,9}}$	$M_{S_{3,9}}$	$-M_{S_{1,12}}$	$-M_{S_{2,12}}$	$M_{S_{3,12}}$
4				$M_{S_{1,1}}$	0	$M_{S_{1,3}}$	$M_{S_{1,10}}$	0	$M_{S_{1,12}}$	$M_{S_{1,7}}$	0	$M_{S_{1,9}}$
5					$M_{S_{1,1}}$	$-M_{S_{2,3}}$	0	$M_{S_{1,10}}$	$-M_{S_{2,12}}$	0	$M_{S_{1,4}}$	$-M_{S_{2,9}}$
6						$M_{S_{3,3}}$	$-M_{S_{1,12}}$	$M_{S_{2,12}}$	$M_{S_{3,12}}$	$-M_{S_{1,9}}$	$-M_{S_{2,9}}$	$M_{S_{3,9}}$
7							$M_{S_{1,1}}$	0	$-M_{S_{1,3}}$	$M_{S_{1,4}}$	0	$-M_{S_{1,6}}$
8								$M_{S_{1,1}}$	$M_{S_{2,3}}$	0	$P_{1,7}$	$M_{S_{2,6}}$
9									$M_{S_{3,3}}$	$-M_{S_{1,6}}$	$-M_{S_{2,6}}$	$M_{S_{3,6}}$
10		SYMMETRIC								$M_{S_{1,1}}$	0	$-M_{S_{1,3}}$
11											$M_{S_{1,12}}$	$-M_{S_{2,3}}$
12												$M_{S_{3,3}}$

Plane stress element mass matrix parameters are given as follows: [1]

$$K_S = \frac{\rho_S . a . b . t_S}{176400}$$
$$M_{S_{1,1}} = K_S \,.\, 21840$$
$$M_{S_{1,6}} = -K_S \,.\, 1540. b$$
$$M_{S_{1,10}} = K_S \,.\, 3780$$
$$M_{S_{2,6}} = -K_S \,.\, 1820. a$$
$$M_{S_{3,3}} = K_S \,.\, 560. (a^2 + b^2)$$
$$M_{S_{3,12}} = -K_S \,.\, 210. (a^2 + b^2)$$
$$M_{S_{1,3}} = -K_S \,.\, 3080. b$$
$$M_{S_{1,7}} = K_S \,.\, 7560$$
$$M_{S_{1,12}} = K_S \,.\, 910. b$$
$$M_{S_{2,9}} = K_S \,.\, 1540. a$$
$$M_{S_{3,6}} = K_S \,.\, 140. (-3a^2 + 2b^2)$$
$$M_{S_{1,4}} = K_S \,.\, 10920$$
$$M_{S_{1,9}} = K_S \,.\, 1820. b$$
$$M_{S_{2,3}} = K_S \,.\, 3080$$
$$M_{S_{2,12}} = -K_S \,.\, 910. a$$
$$M_{S_{3,9}} = K_S \,.\, 140. (2a^2 - 3b^2)$$

2.3. Equation of Motion of the Dynamical System

The system has mass, stiffness, and damping and has movement in just u direction is called a single degree of freedom (Figure 3). According to Newton's second law of motion, the equation of motion of this system is written as Eq.7 [10].

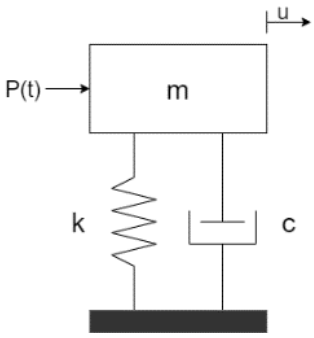

Figure 3. Single degree of freedom system

$$m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g \;\; or \;\; p(t) \qquad (7)$$

Where;

u : Displacement vector
$\dot{u}$: Velocity vector
$\ddot{u}$: Acceleration vector
$\ddot{u}_g$: Ground motion acceleration vector (Earthquake data)
m : System mass
k : System stiffness
c : System damping
$p(t)$: Dynamic load

2.4. Time History Analysis

Time history analysis was performed in YAY2020 software using the Newmark method. Newmark method depends on numerical integration methods to solve Eq.7. In systems of multi-degree freedom, there is a mode that corresponds to each degree of freedom. To consider these modes and study structure as a single part, the equation of motion should be written as Eq.8 [3-8, 10].

$$\Phi^T m\Phi\ddot{q} + \Phi^T c\Phi\dot{q} + \Phi^T k\Phi q = -\Phi^T m\underset{\sim}{I}\ddot{u}_g(t) \quad or \quad \Phi^T p(t) \qquad (8)$$

Eq.8 can be written also as Eq.9.

$$M\ddot{q} + C\dot{q} + Kq = F(t) \qquad (9)$$

Here,

$\boldsymbol{M}$**:** Modal mass matrix

$\boldsymbol{K}$**:** Modal stiffness matrix

$\boldsymbol{C}$**:** Modal damping matrix

$\boldsymbol{q}$**:** Modal displacement vector

$\underset{\sim}{I}$**:** The identity matrix equal in size with the system degree of freedom

The modal matrices M, K, and C here are diagonal matrices. Meanwhile, m, k, and c system matrices have both diagonal and non-diagonal elements

In the Newmark numerical calculation method, the displacement and velocity changes by the time Δt according to Taylor's series are given in Eqs.10 and 11.

$$u_t = u_{t-\Delta t} + \Delta t\dot{u}_{t-\Delta t} + \frac{\Delta t^2}{2}\ddot{u}_{t-\Delta t} + \frac{\Delta t^3}{6}\dddot{u}_{t-\Delta t} + \cdots \tag{10}$$

$$\dot{u}_t = \dot{u}_{t-\Delta t} + \Delta t\ddot{u}_{t-\Delta t} + \frac{\Delta t^2}{2}\dddot{u}_{t-\Delta t} + \cdots \tag{11}$$

Newmark abbreviated Eq.10 and Eq.10 by using β and γ Newmark constants as Eqs.12 and 13.

$$u_t = u_{t-\Delta t} + \Delta t\dot{u}_{t-\Delta t} + \frac{\Delta t^2}{2}\ddot{u}_{t-\Delta t} + \beta\Delta t^3\dddot{u}_{t-\Delta t} \tag{12}$$

$$\dot{u}_t = \dot{u}_{t-\Delta t} + \Delta t\ddot{u}_{t-\Delta t} + \gamma\Delta t^2\dddot{u}_{t-\Delta t} \tag{13}$$

The acceleration equation can be written in Eq.14 assuming that the acceleration is linear in the time step.

$$\dddot{u}_t = \frac{(\ddot{u}_t - \ddot{u}_{t-\Delta t})}{\Delta t} \tag{14}$$

If Eq.14 is written in Eq.12 and Eq.13 the standard form of Newmark equations is obtained as Eqs.15 and 16.

$$u_t = u_{t-\Delta t} + \Delta t\dot{u}_{t-\Delta t} + (\frac{1}{2} - \beta)\Delta t^2\ddot{u}_{t-\Delta t} + \beta\Delta t^2\ddot{u}_t \tag{15}$$

$$\dot{u}_t = \dot{u}_{t-\Delta t} + (1-\gamma)\Delta t\ddot{u}_{t-\Delta t} + \gamma\Delta t\ddot{u}_{t-\Delta t} \tag{16}$$

Displacements, velocities, and accelerations of each node of the system are obtained by iteration of the last two equations by the time.

2.5. Shear Building Analysis

The type of structure that is expected to move only horizontally under various static or dynamic loads without rotation of a horizontal section on the floor level is called Shear Building. It’s also a type of idealization of a building to resist only shear forces without any bending as shown in Figure 4.

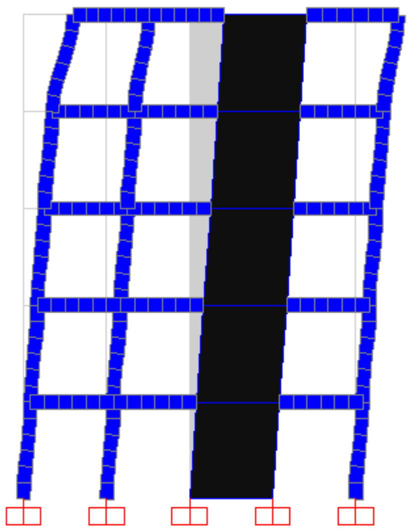

Figure 4. Shear building system example

This method is a quick method for determining the dominant period of structures. It is based on calculating the mass and stiffness of each floor separately and obtaining the general mass and stiffness matrices of the structure. The mass and stiffness matrices of a 5-storey shear structure like shown in Figure 4 are written as Eqs.17 and 18, respectively [14].

$$M_{sis} = \begin{bmatrix} m_1 & 0 & 0 & 0 & 0 \\ 0 & m_2 & 0 & 0 & 0 \\ 0 & 0 & m_3 & 0 & 0 \\ 0 & 0 & 0 & m_4 & 0 \\ 0 & 0 & 0 & 0 & m_5 \end{bmatrix} \tag{17}$$

$$K_{sis} = \begin{bmatrix} k_1 + k_2 & -k_2 & 0 & 0 & 0 \\ -k_2 & k_2 + k_3 & -k_3 & 0 & 0 \\ 0 & -k_3 & k_3 + k_4 & -k_4 & 0 \\ 0 & 0 & -k_4 & k_4 + k_5 & -k_5 \\ 0 & 0 & 0 & -k_5 & k_5 \end{bmatrix} \tag{18}$$

Here,

M_{sis}: System mass matrix

K_{sis}: System stiffness matrix

m_i: Total mass of i floor

k_i: Total stiffness of i floor

2.6. Wide Column Analysis

A wide column is an easy method to analyze structure without using shear wall formulations. It depends on replacing the shear wall with a wide column that has the same rigidity and mass as the shear wall and places rigid beams at each floor level as shown in Figure 5.

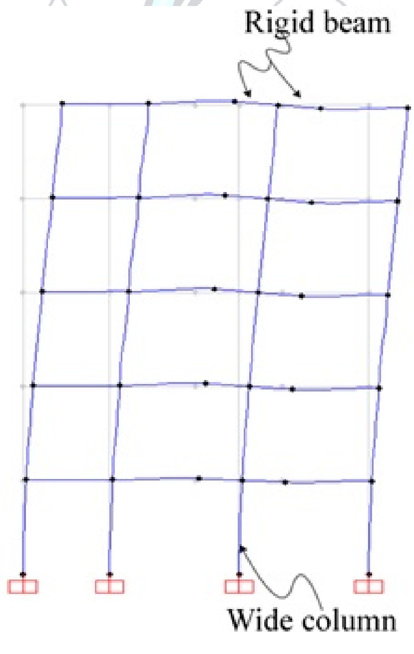

Figure 5. Wide column system example

3. RESULTS AND DISCUSSION

In this section, some examples will be solved dynamically using YAY2020 and compared with SAP2000.

3.1. Shear Wall-Frame Structure

A 3-storey 4-span shear wall-frame structure is analyzed by YAY2020 (Figure 6). All storey heights are $h = 350\ cm$ and span distance $L = 300\ cm$. Shear walls are located between the 3rd and 4th axes. The properties of all frame elements are the same and they are square in shape. Frame elements cross sectional-area $A = 2500\ cm^2$, Modulus of elasticity $E = 13025000\ N/cm^2$, a moment of inertia $I = 520833.33\ cm^4$ and mass per unit volume $\rho = 0.00025\ kg/cm^3$. Shear wall elements have the same modulus of elasticity and mass per unit volume of frame elements. Shear wall elements thickness $t = 50\ cm$ and Poisson ratio $\upsilon = 0.2$. A 1000 N single loads applied on the top-left and top-right points of the structure. Figure 7 shows the results of the time history analysis of the shear wall-frame structure as a displacement-time graph of joint 20 in x-direction under the Chūetsu 6.6 magnitude earthquake which happened in Japan in 2007. The obtained modal analysis result by YAY2020 and Sap2000 are given in Table 2. The table shows that YAY2020 can find 45 modes meanwhile; the SAP2000 can just find 30 modes.

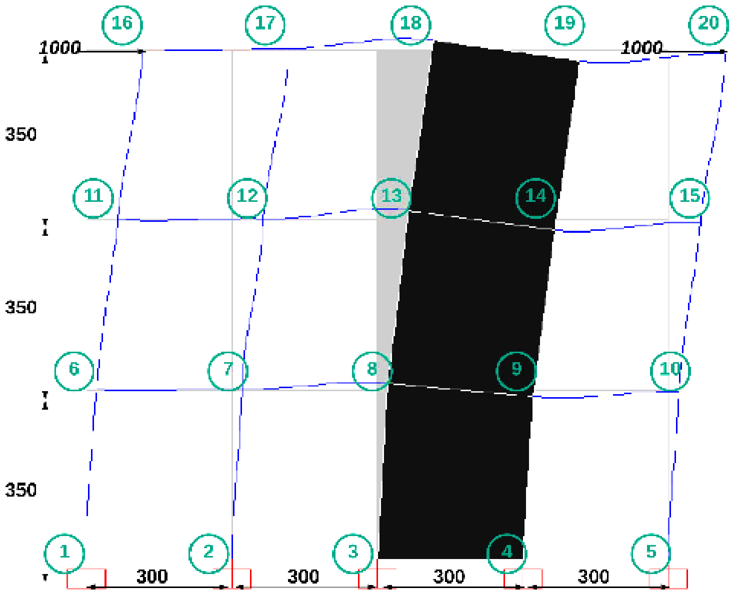

Figure 6. Shear Wall-Frame Structure

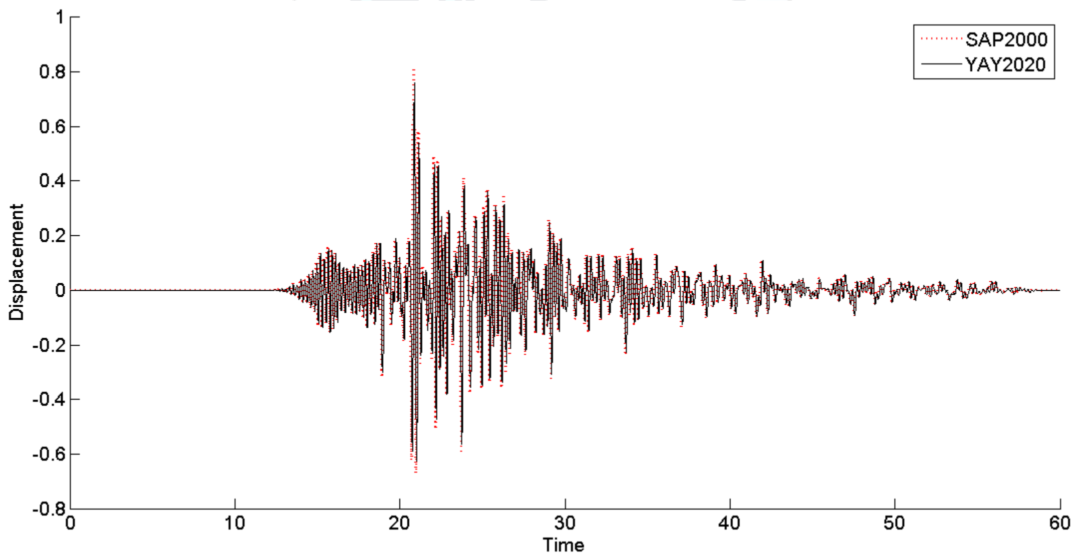

Figure 7. Shear wall-frame structure displacement-time graph

Table 2. Modal analysis of the shear wall-frame structure

SAP2000 – Modal analysis					YAY2020 - Modal analysis				
Mode	**Period**	**Frequency**	**Angular frequency**	**Eigenvalues**	**Mode**	**Period**	**Frequency**	**Angular frequency**	**Eigenvalues**
No	sec	cyc/sec	rad/sec	rad2/sec2	No	sec	cyc/sec	rad/sec	rad2/sec2
1	0.23965	4.17	26.22	687.40	1	0.2365	4.23	26.56	705.65
2	0.06172	16.20	101.80	10363.00	2	0.0798	12.52	78.69	6191.98
3	0.05064	19.75	124.09	15397.00	3	0.0554	18.06	113.45	12871.27
4	0.04506	22.19	139.45	19446.00	4	0.0488	20.50	128.78	16583.93
5	0.04456	22.44	141.01	19884.00	5	0.0415	24.11	151.47	22943.98
6	0.04011	24.93	156.66	24543.00	6	0.0407	24.55	154.25	23794.06
7	0.03809	26.26	164.97	27214.00	7	0.0392	25.54	160.45	25745.63
8	0.03180	31.45	197.59	39040.00	8	0.0339	29.47	185.19	34296.32
9	0.02797	35.75	224.64	50464.00	9	0.0327	30.63	192.44	37032.71
10	0.02589	38.63	242.71	58910.00	10	0.0312	32.00	201.09	40436.20
11	0.02038	49.06	308.24	95012.00	11	0.0306	32.65	205.15	42087.69
12	0.01981	50.49	317.24	100640.00	12	0.0293	34.14	214.49	46007.44
13	0.01924	51.99	326.64	106690.00	13	0.0254	39.32	247.06	61039.49
14	0.01721	58.12	365.16	133340.00	14	0.0239	41.77	262.47	68888.93
15	0.01717	58.25	365.99	133950.00	15	0.0223	44.82	281.64	79322.14
16	0.01715	58.31	366.35	134220.00	16	0.0206	48.59	305.32	93219.59
17	0.01605	62.30	391.42	153210.00	17	0.0192	52.08	327.24	107082.83
18	0.01513	66.09	415.27	172450.00	18	0.0175	57.20	359.39	129157.94
19	0.01470	68.01	427.32	182600.00	19	0.0170	58.82	369.58	136591.09
20	0.01435	69.68	437.82	191680.00	20	0.0164	61.11	383.95	147418.32
21	0.01432	69.85	438.85	192590.00	21	0.0146	68.61	431.06	185811.85
22	0.01315	76.04	477.78	228270.00	22	0.0142	70.38	442.20	195536.48
23	0.01285	77.80	488.82	238950.00	23	0.0137	72.90	458.03	209794.57
24	0.01248	80.15	503.61	253630.00	24	0.0135	74.33	467.02	218111.60
25	0.01247	80.18	503.79	253810.00	25	0.0127	78.71	494.52	244554.70
26	0.01197	83.54	524.89	275510.00	26	0.0127	79.05	496.68	246693.99
27	0.01120	89.26	560.86	314560.00	27	0.0119	83.72	526.05	276732.32
28	0.01105	90.50	568.64	323360.00	28	0.0112	89.25	560.75	314445.91
29	0.00981	101.96	640.62	410400.00	29	0.0110	91.19	572.95	328270.69
30	0.00859	116.48	731.88	535640.00	30	0.0104	96.59	606.92	368355.92
					31	0.0103	96.81	608.31	370036.87
					32	0.0097	102.68	645.13	416195.93
					33	0.0090	110.94	697.06	485895.27
					34	0.0085	117.96	741.16	549313.12
					35	0.0083	120.35	756.16	571784.18
					36	0.0075	134.11	842.62	710005.68
					37	0.0072	138.05	867.40	752382.60
					38	0.0066	152.30	956.93	915721.14
					39	0.0059	168.39	1058.01	1119385.88
					40	0.0051	196.84	1236.81	1529695.64
					41	0.0050	200.00	1256.63	1579119.41
					42	0.0048	206.24	1295.86	1679246.66
					43	0.0048	208.54	1310.32	1716941.94
					44	0.0043	230.93	1450.97	2105302.50
					45	0.0033	300.63	1888.88	3567881.43

3.2. Period-Based Comparison of Shear Building and Wide Column

A 5-story planar shear wall-frame system which is shown in Figure 4 adopted to study.

Table 3. Period analysis-based comparison of the normal FEM, shear building, and wide column methods

Mode number	Normal FEM		Wide Column		Shear building	
	YAY2020	SAP2000	YAY2020	SAP2000	YAY2020	SAP2000
1	0.48545	0.49573	0.47530	0.50270	0.50559	0.51791
2	0.13537	0.12554	0.11294	0.12730	0.17419	0.17843
3	0.10084	0.07821	0.07723	0.07825	0.11179	0.11452
4	0.07569	0.07005	0.06807	0.07022	0.08861	0.09077
5	0.06379	0.06517	0.06001	0.06517	0.07951	0.08145
6	0.06220	0.06092	0.05429	0.06076		
7	0.05564	0.05791	0.04881	0.06001		
8	0.04458	0.04064	0.03564	0.04266		
9	0.03848	0.03692	0.03460	0.03779		
10	0.03543	0.03243	0.03135	0.03150		
Max. mode No.	75	50	60	40	5	5

All floors' height is 350 cm. All elements Modulus of elasticity $= 3180098.312\ N/cm^2$, Poisson ratio $\upsilon = 0.2$ and unit volume mass of concrete $\rho = 0.00025\ kg/cm^3$. All frame elements cross sectional-area $A = 2500\ cm^2$ and moment of inertia $= 520833.33\ cm^4$. Table 3 comparing the first system 10 periods calculated with normal FEM, wide column, and shear building analyzing methods.

4. CONCLUSIONS

In the modal analysis, YAY2020 can find more modes than SAP2000. Since SAP2000 isn't added the angular rotation perpendicular to the plate into the calculation of shear wall stiffness and mass matrices and the system mass matrix has just diagonal elements. These reasons decreased the degree of freedom of the system causing decreased mode's number.

The displacement values calculated by YAY2020 are lower than those calculated by SAP2000 because YAY2020 uses a full stiffness matrix, which a little bit increased the rigidity of the structure.

The modal analysis values obtained using a wide column are close to the values obtained using a regular shear wall. Because the wide column and shear building have the same mass and stiffness values. So, building mass and stiffness matrices are preserved as a whole.
Shear building analysis quickly gives the dominant period of the structure and this value is close to the real one.

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BIOGRAPHY

Ragıb Sabah was born in 1993. He is also known as Ragheb Alsabbagh. In 2014 Mr. Sabah started his undergraduate degree in the Civil Engineering Department at Pamukkale University in Turkey and graduated in 2018 with high honor degree. In 2021, Mr. Sabah completed his master's degree at Istanbul University-Cerrahpasa. He is interested in computational sciences, applicable technology, and management areas.

REFERENCES

[1]. Öztorun N.K., (2006) *"A rectangular finite element formulation"*, Finite Elem. Anal. Des. 42 (12), 1031–1052.

[2]. Öztorun N.K., (2007) *Reply to "discussion on: 'Rectangular finite element formulation"*, Finite Elements in Analysis and Design 43, 733 – 736.

[3]. Ed. Wilson, (2002) *"Three-Dimensional Static and Dynamic Analysis of Structures"*, Computers and Structures Inc. University of California, Berkeley, USA.

[4]. Computers and Structures, Inc. (2016*) "SAP2000 CSI Analysis Reference Manual, Structural Analysis Program"*, California, Berkeley, USA.

[5]. Ed. Wilson, (1991) *"Computer Assisted Learning of Static and Dynamic Analysis of Structural Systems user's manual"*, University of California, Berkeley, USA.

[6]. Ed. Wilson, E. Ray, W. Clough, (1952) *"Dynamic response by step-by-step matrix analysis"*, Computers in Civil Engineering Symposium.

[7]. Ed. Wilson, Bathe K.J., L. Farhoomand, (1973) *"Nonlinear dynamic analysis of complex structures"*, earthquake engıneerıng and structural dynamıcs, 1, 241-252

[8]. Bathe K.J., (2014*) "Finite Element Procedures Second edition"*, Prentice-Hall, Pearson Education, Inc. 978-0-9790049-5-7.

[9]. Newmark, (1959) *"A method of computation for structural dynamics'"*, Engineering Mechanics Division. 2094.

[10]. Chopra, A.K, (1995) *"Dynamics of Structures: Theory and Applications to Earthquake Engineering"*, Prentice-Hall, Englewood Cliffs, New Jersey, ISBN: 0-13-855214-2.

[11]. E., Öztorun, 2020, *"Köprülerin Deprem Etkileri Altındaki Davranışları"*, Thesis (PhD), Istanbul University.

[12]. E., Öztorun, N.K., Öztorun ve C., Alhan 2019, *"Yapıların Düşey Deprem Etkisi Altındaki Davranışları: Bir Köprü Örneği",* 21. Ulusal Mekanik Kongresi, 02-06 Eylül. 2019, Niğde Ömer Halisdemir Üniversitesi, Niğde, 57-65.

[13]. Timoshenko S., Goodier J.N., (1951) *"Theory of Elasticity"*, McGraw-Hill, New York.

[14]. Paz M., Leigh W., (1991) *"Structural Dynamics"*, Kluwer Academic Publishers Springer Science Business Media Dordrecht.

[15]. Adams J. C., Brainerd W.S., Martin J.T., Smith B.T., Wagener J.L., (1992) *"Fortran 90 Handbook"*, Library of Congress Catalog Card Number 91-77211.