



**İstanbul
Bilgi Üniversitesi**

DAMAGE DETECTION THROUGH DYNAMIC ANALYSIS

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ABSTRACT

Structural health monitoring basically means continuous or periodic monitoring and analysis of important indicators of a structure. In general, it is possible to solve the dynamic behavior of the structure, which is the signature of the structure, in real time with the accelerometers placed in the structure. The dominant period, damping rates, modal frequencies, mode shapes natural swing modes, interfloor shift rates are included in this analysis. Thus, it is possible to realize whether there has been a change in these parameters, which are indicative of the changes in the structural system of the building, in a period of minutes when the building has experienced an earthquake. In this modal base simulation, the purpose of the building monitoring systems used in earthquake engineering, the methods used and how they are used and interpreted are explained. In addition, the article discusses how to place the sensors used in building health monitoring systems in the building, and then describe some methods on how to analyze the recorded data. The most important step in using building health monitoring systems in practice is to analyze the records correctly. With the methods we use after the analysis, the modal characteristics (periods, mode shapes, damping ratios) of the building, the amplitude and periods of torsion and oscillation vibrations in the building, the damage rates received by certain columns, and whether there is a structure-ground interaction in the structure and if any, its order can be easily determined. In the modal base simulation mentioned in the modal base simulation, a specific structure was designed in columns and materials in SAP2000 program. Different material types were also used when determining the materials, so modulus of elasticity was reduced and interpreted as if the concrete was damaged. In this way, the material properties were gradually reduced, and the concrete was interpreted as damaged concrete. Afterwards, the columns on certain floors of the building were damaged in this way and in the SAP2000 program the structure was moved with its own load. The displacement analyzed after this concussion found damage to the column in which floor of the building.

Key words: Structural health monitoring, mode shape curvature, damage detections and ratio, local damage, using different materials, dynamic analysis

1.INTRODUCTION

1.1 Structural Health Monitoring System

Structural Security Monitoring (SHM) helps us make a strategy plan for damage assessment of structures such as bridges and buildings.

Here damage is characterized as changes to a structural system's material and/or geometric properties including changes to boundary conditions and system connectivity, which adversely affect the performance of the system. .[1]

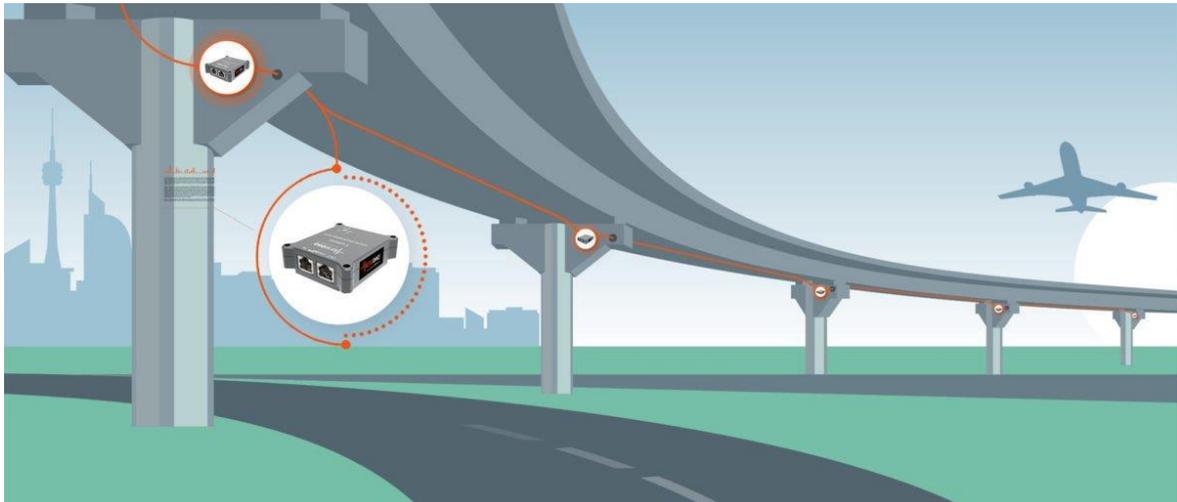


Figure 1: Accelerometer Placement In Bridges [2]

The SHM method involves monitoring a device over time using regularly sampled response measurements from a variety of sensors (often inertial accelerometers), Extracting Damage sensitive characteristics from those measurements, and statistical analysis of those characteristics to determine the current state of system safety.

After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure. [3]

Inspection of infrastructure, such as road network and bridges, plays a crucial role in public safety with respect to both long-term accumulation of damage and post-extreme event scenarios. [4]

Since a long time, both qualitative and non-continuous approaches have been used to test systems since their capacity to fulfill their intended function.

The sound of a hammer hitting the train wheel has been used by railroad Wheel tappers since the beginning of the 19th century to determine whether harm was present.

There are two techniques in the field of SHM which are wave propagation-based techniques **Raghavan and Cesnik**, and **vibration-based techniques**.

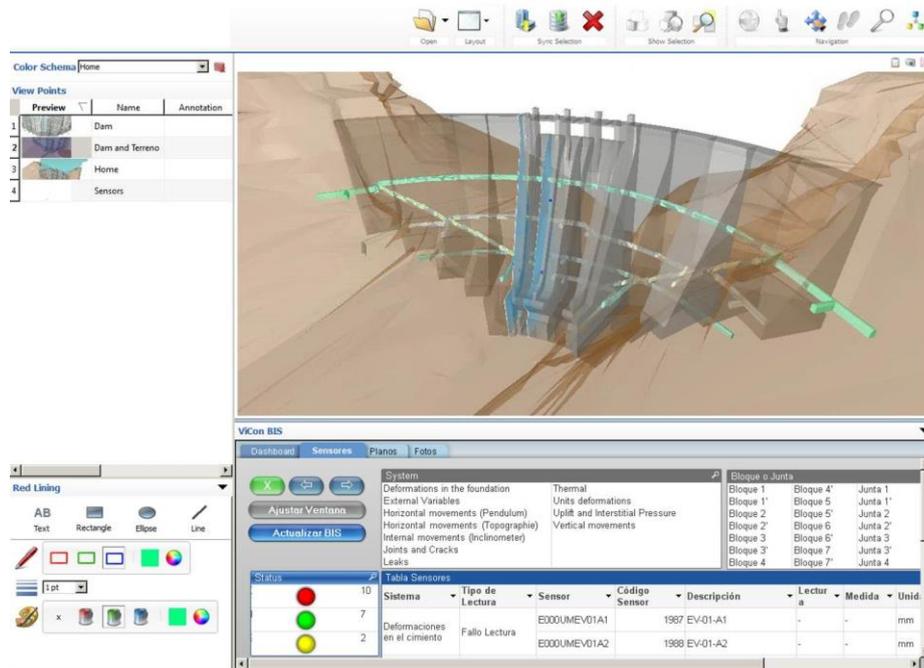


Figure 2: BIM Systems Model [5]

As we see in the figure, some program used for creating models to defined damage place. By connecting various kinds of data to 3D models, BIM generates added value and synergies. [6]

This approach combines 3D dam model with surveillance and safety-related details. DAMDATA provides maintenance work, visual checks, and monitoring data. A goal-oriented understanding about the structure's safety status is formed through a bidirectional connection between the 3D model and the integrated details.

The SHM problem can be addressed in the context of a statistical pattern recognition paradigm. [7] This paradigm can be broken down into three parts:

1.1.1 Statistical pattern recognition

Operational Evaluation,
Data Acquisition and Cleansing,
Feature Extraction and Data Compression, and
Statistical Model Development for Feature Discrimination.

1.1.2 Health evaluation of constructed bridge, building and other associated infrastructures

Detecting the existence of structural damages

Locating the damage

Determining the types of damage

Quantifying the seriousness of the damage

Signal processing and statistical classification must be employed to convert sensor data on infrastructural health status into assessment damage info.

1.2.3 Operational Assessment

There are four question that need to answer for operational assessment.

What is life-safety and/or economic reason for the actions of the SHM?

How is damage defined for the system under investigation, and for multiple possibilities of damage, which cases are of the greatest concern?

What are the conditions under which the system to be monitored functions, both operational and environmental?

What limitations are there to the acquisition of data in the operating environment?

1.1.4 Measurement Systems



Figure 3: All In One Systems[8]



Figure 4: TRIONet Distributed Systems [8]



Figure 5: Acquisition and Amplifier Modules [8]

1.1.5 Systems

The feasibility of such a solution is extremely important because of the constant monitoring criteria at several measurement points around the system.

MEMS technology turns out to be mature enough at this point and an ideal choice for the demanding application. MonoDAQ-E-gMeter builds on the flexibility of the MonoDAQ-E product line (EtherCAT connectivity, 50 m module-to-module distance, single network cable, up to 48 V power supply, DEWESoft software) and includes a triaxial low-noise precision MEMS accelerometer that is comparable in performance to the special seismic accelerometers.

Advanced engineering methods including signal filtering, integration to velocities and displacements, frequency domain analysis and complex statistics can be implemented inside DEWESoft software with low set-up effort and no special programming skills. The same is true for exporting to a database, 3rd party software format or sending the data using protocols such as OPC UA. [9]

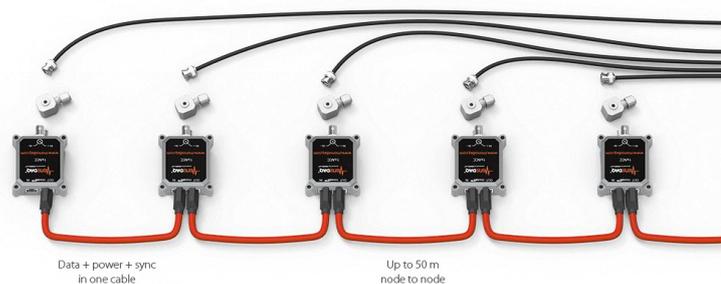


Figure 6: Accelerometer System[9]



Figure 7: Accelerometer System Unit [9]

As we can see the in the figure, we see application method of SHM system in bridge. In this case of damage, we have notified us at the same time.

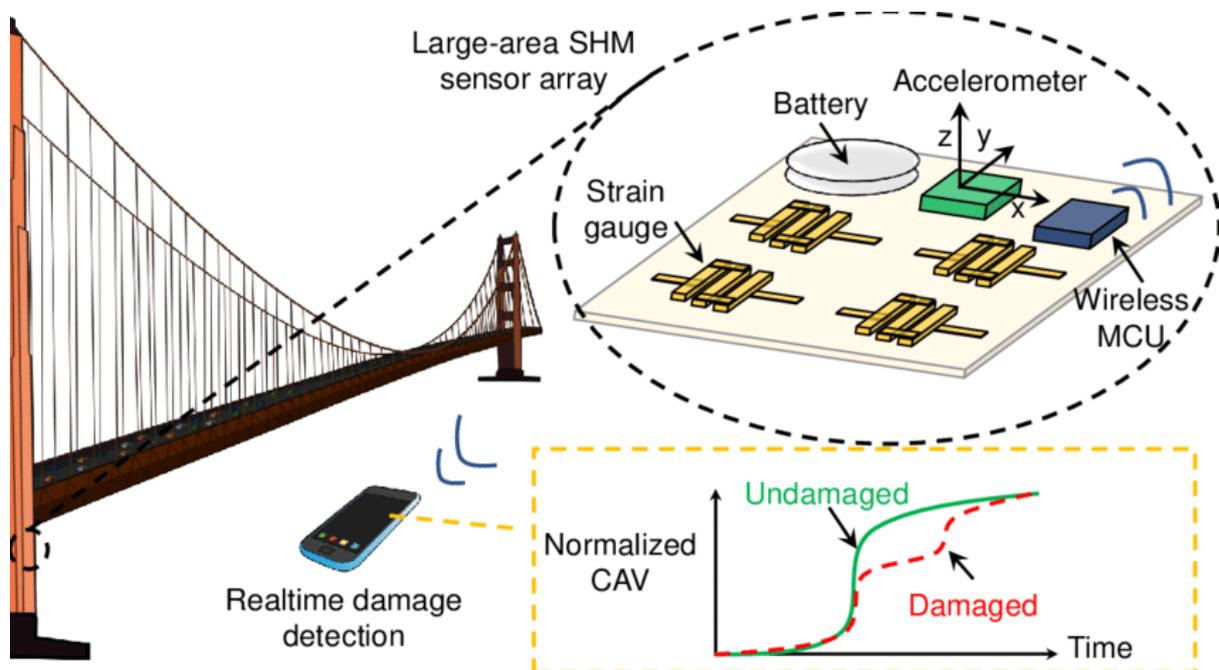


Figure 8: SHM System on bridge [10]

Since we focus on damage to the structure, we need to know some basic knowledge. Building damage can happen for many reasons such as earthquake, duration of time or earth load.

1.1.6 Internal Forces and Acceleration

According to research the basic information needs to know, the seismic body and surface waves create inertial forces within the building. Inertial forces are created within an object when an outside force tries to make it move if it is at rest or changes its rate or direction of motion if it is moving. Inertial force takes us back to high school physics and to Newton's Second Law of Motion, for when a building shakes it is subject to inertial forces and must obey this law just as if it were a plane, a ship, or an athlete. Newton's Second Law of Motion states that an inertial force, F , equals mass, M , multiplied by the acceleration, $F=m.a$ [11]

1.1.7 Duration, Velocity, and Displacement

Because of the inertial force formula, acceleration is a key factor in determining the forces on a building, but a more significant measure is that of acceleration combined with duration, which takes into account the impact of earthquake forces over time. In general, a number of cycles of moderate acceleration, sustained over time, can be much more difficult for a building to withstand than a single much larger peak. Continued shaking weakens a building structure and reduces its resistance to earth-quake damage.[11]

A useful measure of strong-motion duration is termed the bracketed duration.

1.1.8 Period and Resonance

Another very important characteristic of earthquake waves is their period or frequency; that is, whether the waves are quick and abrupt or slow and rolling. This phenomenon is particularly important for determining building seismic forces.

All objects have a natural or fundamental period; this is the rate at which they will move back and forth if they are given a horizontal push

. In fact, without pulling and pushing it back and forth, it is not possible to make an object vibrate at anything other than its natural period.

Period is the time in seconds (or fractions of a second) that is needed to complete one cycle of a seismic wave. Frequency is the inverse of this the number of cycles that will occur in a second and is measured in "Hertz". One Hertz is one cycle per second.[11]

Natural periods vary from about 0.05 seconds for a piece of equipment, such as a filing cabinet, to about 0.1 seconds for a one-story building. Period is the inverse of frequency, so the cabinet will vibrate at $1 \text{ divided by } 0.05 = 20$ cycles a second or 20 Hertz.

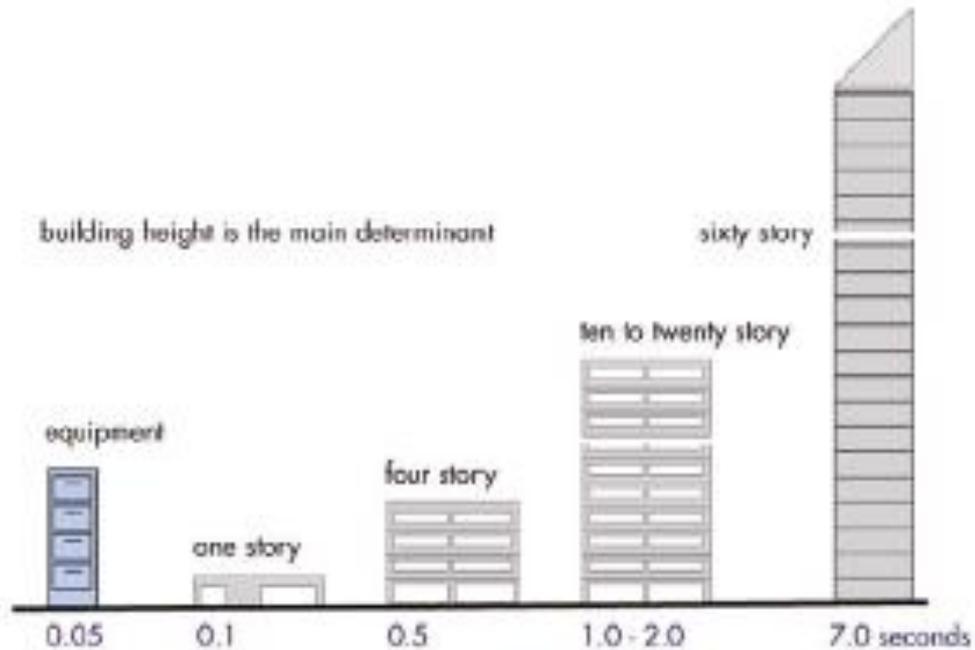


Figure 9: Periods of buildings[13]

Comparative building periods determined by height. These values are approximations: the structural system, materials, and geometric proportions will also affect the period.[12]

1.1.9 Ground Motion, Building Resonance, and Response Spectrum

When a vibrating or swinging object is given further pushes that are also at its natural period, its vibrations increase dramatically in response to even rather small pushes and, in fact, its accelerations may increase as much as four or five times. This phenomenon is called resonance.

The ground, if set in motion by an earthquake, obeys the same physical law and vibrates at its natural period.

Ground ranges from approximately 0.4 seconds to 2 seconds depending on the condition of the soil.

Hard ground or rock will experience short period vibration. Very soft ground can have a time of up to 2 seconds but, unlike a structure, it cannot withstand motions for longer periods even in certain special circumstances.

Since this range falls well within the common range Time to repair, it's very likely that the earthquake moves the ground movement of the building will occur during the natural period of Construction. This can create resonance, causing the structure to encounter accelerations of maybe 1 g when the ground vibrates only with speeds of 0.2 g. [12]

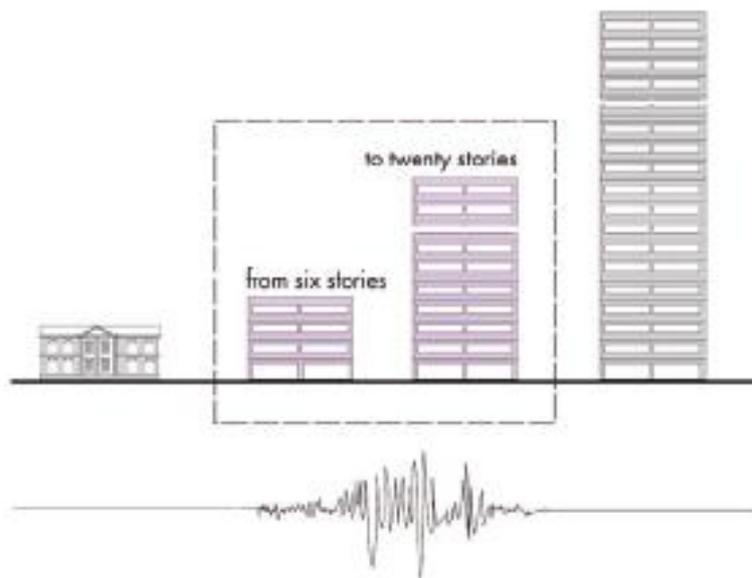


Figure 10: Comparing periods of 6 and 20 stories building

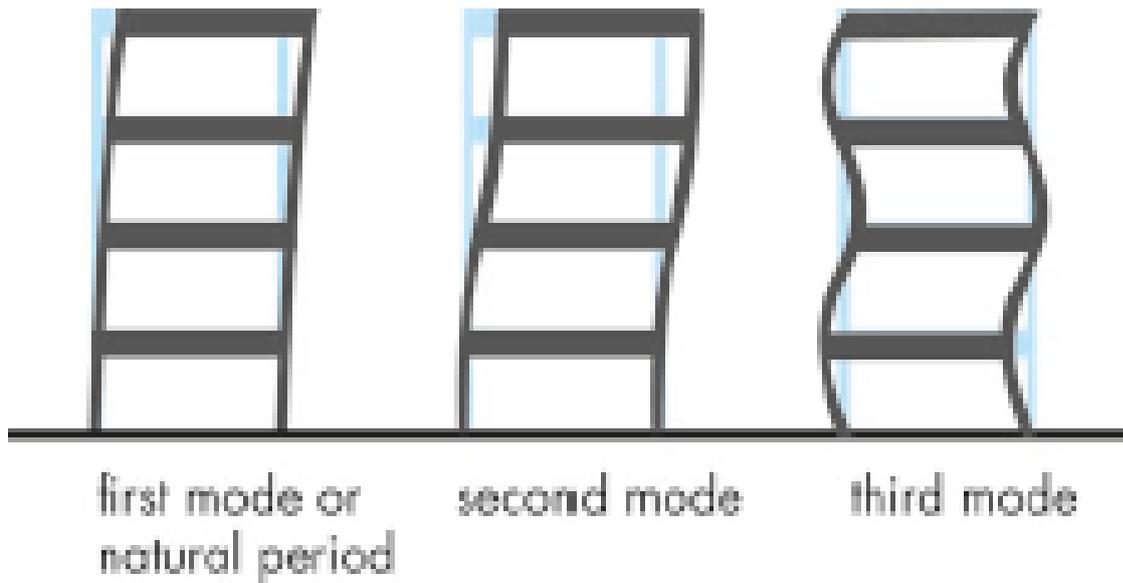


Figure 11: Modes of vibration.[13]

1.1.10 Ductility

The gap between design capacity (the theoretical ability of a building to withstand calculated forces) and possible actual forces is, finally, largely dealt with by relying on the material property of ductility. This is the property of certain materials (steel in particular) to fail only after considerable inelastic deformation has taken place, meaning that the material does not return to its original shape after distortion. This deformation, or distortion, dissipates the energy of the earthquake.

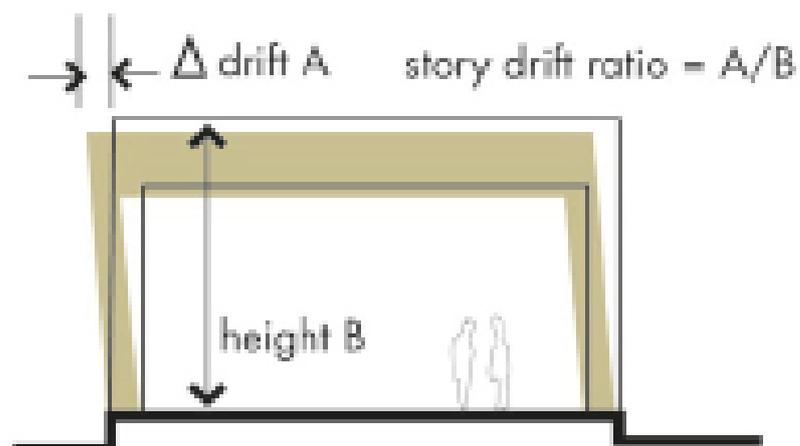


Figure 12: Story Drift Ratio [13]

1.2 Mode Shape Curvature

If damage occurs on a structural component, it affects the dynamic parameters (vibration periods, damping ratios and mode shapes) of the system.

Monitoring how the mode shapes change helps us understand the location and extent of the damage.

For instance, below you can see some result from our simulation, 1st mode shape for a 15-story building in X direction. In the table, the column at each story is damaged gradually and the corresponding mode shape need to draw.

Joint	Health	Mode1_X_0	Mode1_X_10	Mode1_X_20	Mode1_X_30	Mode1_X_40	Mode1_X_50	Mode1_X_60	Mode1_X_70	Mode1_X_80	Mode1_X_90	Mode1_X_100(KAT)
1		0	0	0	0	0	0	0	0	0	0	0
2	0,001531	0,001531	0,00153	0,001528	0,001526	0,001523	0,00152	0,001515	0,001508	0,001496	0,001471	0,00138
41	0,003834	0,003834	0,003828	0,003822	0,003814	0,003804	0,003792	0,003775	0,003752	0,003717	0,003647	0,003414
61	0,00623	0,00623	0,006235	0,006239	0,006244	0,006249	0,006254	0,006256	0,006255	0,006242	0,006191	0,005914
81	0,008626	0,008626	0,008628	0,00863	0,008631	0,008632	0,008633	0,008631	0,008623	0,008604	0,008547	0,008274
101	0,010986	0,010986	0,010987	0,010989	0,01099	0,01099	0,01099	0,010987	0,010979	0,010959	0,010903	0,010642
121	0,013285	0,013285	0,013285	0,013286	0,013286	0,013285	0,013284	0,01328	0,013271	0,013251	0,013196	0,012951
141	0,015497	0,015497	0,015497	0,015496	0,015496	0,015494	0,015492	0,015487	0,015478	0,015458	0,015406	0,015182
161	0,017598	0,017598	0,017597	0,017597	0,017596	0,017594	0,01759	0,017585	0,017576	0,017557	0,017511	0,017314
181	0,019566	0,019566	0,019566	0,019564	0,019563	0,019561	0,019557	0,019552	0,019543	0,019527	0,019487	0,019326
201	0,021381	0,021381	0,02138	0,021379	0,021377	0,021375	0,021371	0,021367	0,021359	0,021346	0,021317	0,021199
221	0,023023	0,023023	0,023022	0,023021	0,023019	0,023017	0,023014	0,023011	0,023005	0,022997	0,02298	0,022916
241	0,024476	0,024476	0,024475	0,024473	0,024472	0,024471	0,024469	0,024467	0,024465	0,024463	0,024461	0,024461
261	0,025723	0,025723	0,025723	0,025722	0,025721	0,025721	0,025721	0,025721	0,025723	0,025728	0,025745	0,02582
281	0,026754	0,026754	0,026754	0,026754	0,026754	0,026755	0,026757	0,02676	0,026767	0,026782	0,02682	0,026981
301	0,027559	0,027559	0,027559	0,02756	0,027562	0,027565	0,027569	0,027576	0,027589	0,027615	0,027677	0,027935
321	0,028149	0,028149	0,028151	0,028153	0,028157	0,028162	0,028169	0,028181	0,0282	0,028238	0,028328	0,028694

Table1 : Displacement of Mode 1 – X Direction

1.2.1 How to Calculate Rotation Angles

The modes shapes calculated on the healthy structure is used as reference.

In the rotation graph x axis represents the modal amplitudes in the healthy state and y axis corresponds to the modal amplitudes in the damaged state.

$$\%Damage = \left(1 - \frac{\text{Stiffness of the damaged column}}{\text{Stiffness of the healthy column}} \right) \times 100$$

Figure 13: Calculation of rotation Angle

If damage index is zero $\phi_{i,1,dam} = \phi_{i,1,n} \Rightarrow y = x$ graph.

In the figure we see, example of How Un-damaged Building and how damaged building. According that we find rotation angle.

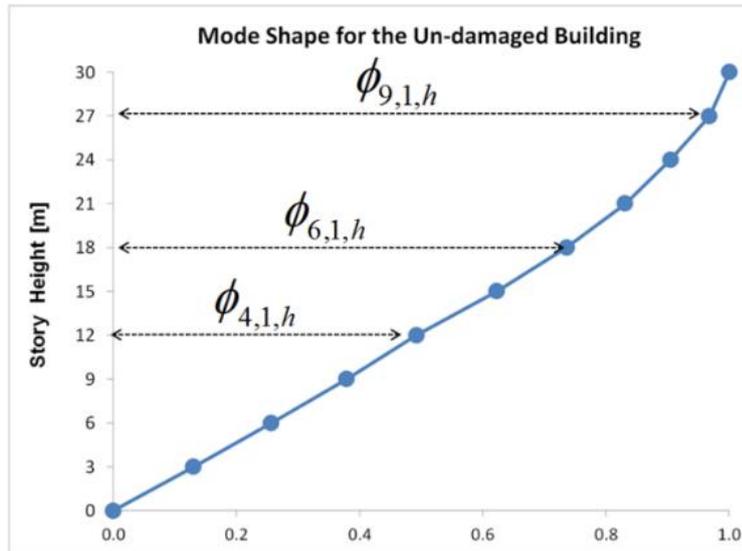


Figure 14: Un-damaged Building Example

$\phi_{9,1,h}$: Mode number 1, modal amplitude of the 9th joint on healthy structure

$\phi_{9,1,dam}$: Mode number 1, modal amplitude of the 9th joint on damaged structure

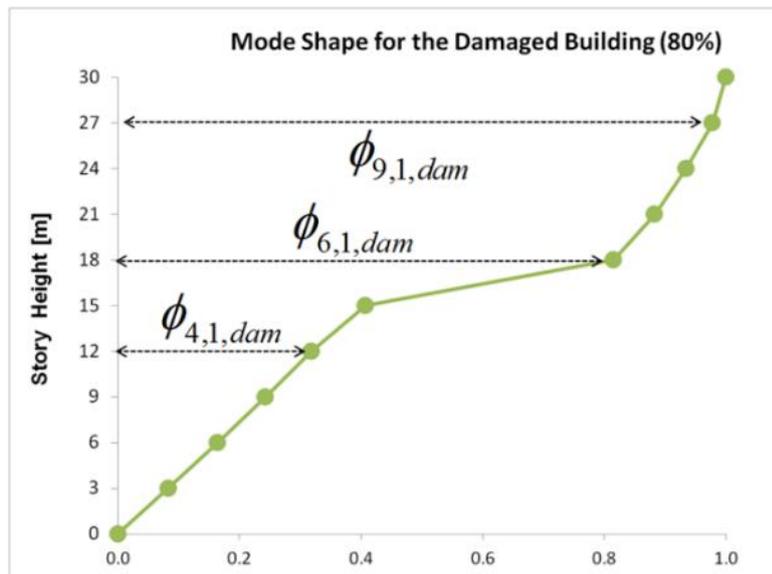


Figure 15: Damaged Building Example

1.2.2 Change of Angle vs. Damage Index

Below you can see the rotation angles calculated by using the 1st mode shape.

In the first graph the column at the 3rd story is damaged gradually and the corresponding angles are calculated.

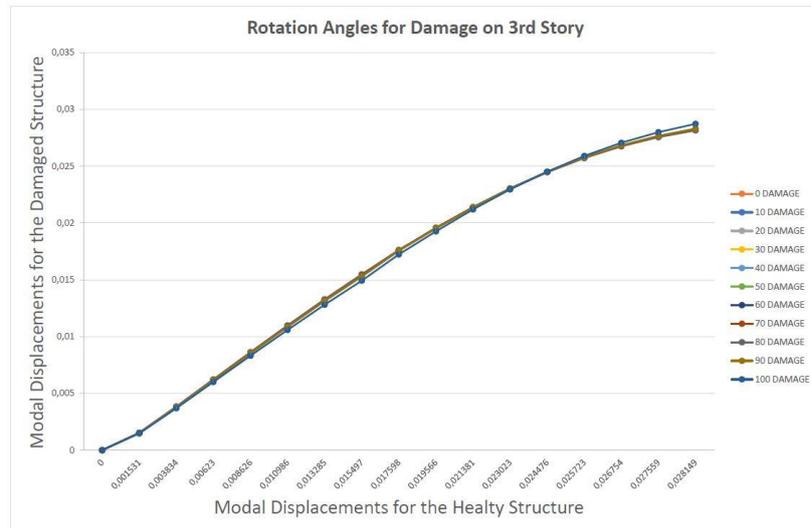


Figure 16: 3rd story is damaged

In the second graph the column at the 8th story is damaged and the corresponding angles are calculated. As can be seen in the graph only the end joints of the damaged stories experience a relative rotation.

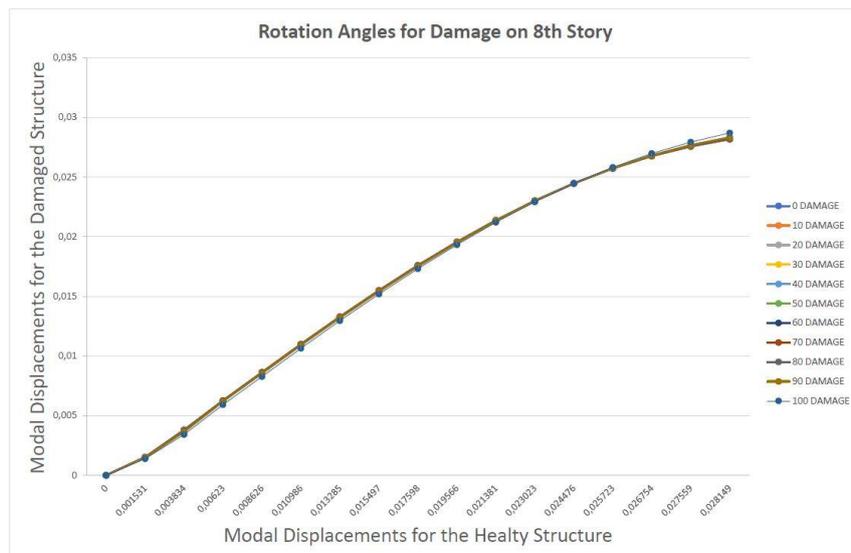


Figure 17: 8th story is damaged

Once these rotations are calculated for different stories and damage levels, it was observed that they mainly change depending on the damage level. On the contrary, these curves do not change depending on the damage location. The rotations of the 3rd story columns are more or less the same as the rotations of the 8th story columns. Below you can see the rotations calculated for different damage cases simulated on a 15-story building. The columns of each story is damaged gradually and the corresponding rotation angles are calculated. The figure clearly shows that the columns behave.

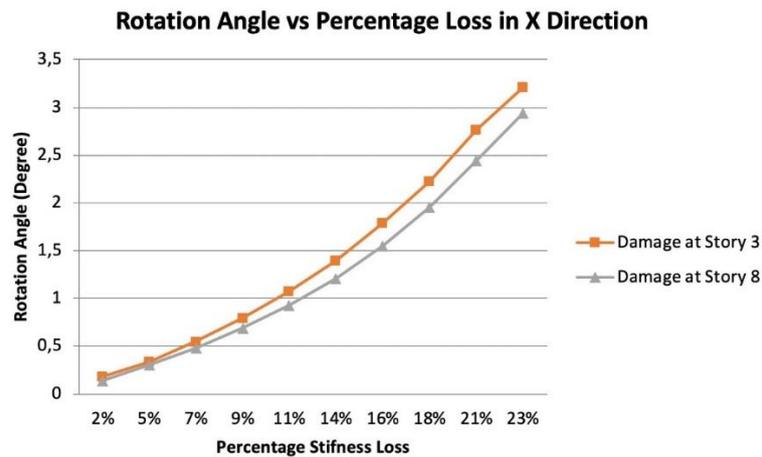


Figure 18: Rotation Angle vs Percentage in X Direction

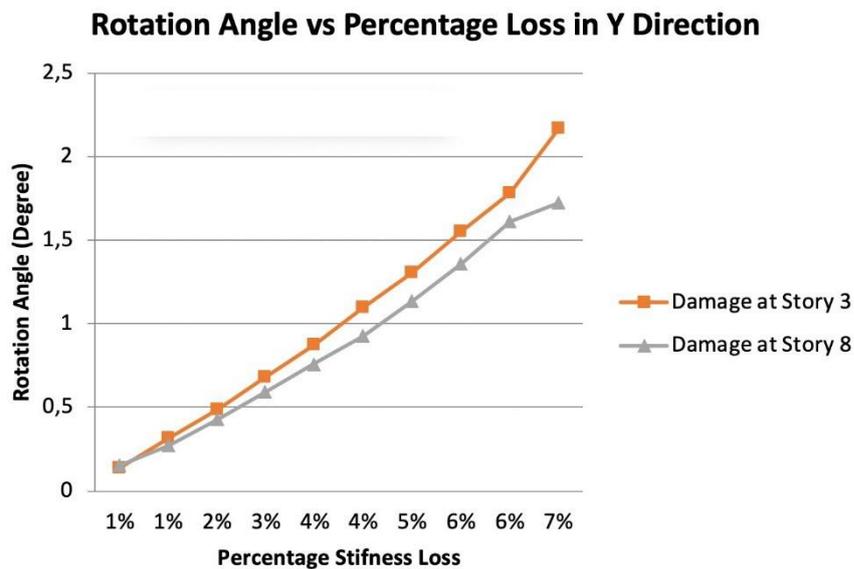


Figure 19: Rotation Angle vs Percentage In Y direction

2. MATERIALS AND METHODS

2.1 SAP2000

As you know, we use some programs to make a model of buildings. We will get help from SAP2000 program to create a building model for ourselves while we do our project. This program provides us with many conveniences for the project phase of our structure. We spent a lot of our time doing this project on this program. Many structural operations can be solved in this program. But at this stage we have used the parts that are relevant to our subject that are relevant to us. We can examine many methods of analysis with SAP2000 such as Static and Dynamic Analysis, Linear and Nonlinear Analysis, Bridge Analysis etc. In short, we will make a model of our building from SAP2000 and examine the displacements of joints.

2.2 Materials and Modelling

We will need a floor plan to do modeling first. You can see our floor plan in the picture below. The short edge of our building is 15 meters and the long edge is 16 meters. We can call each of the lines that appear in the floor plan an axle. At the intersection of these axles are our columns. There are 6 different types of columns in this plan.

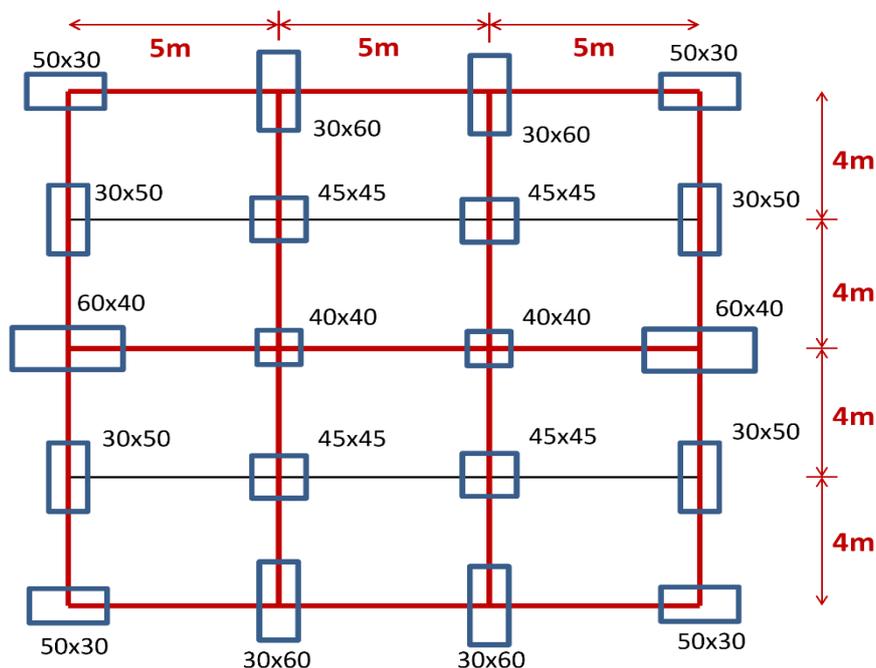


Figure 20: Floor Plan

We start by entering the axle distances first when creating the first stage of the model in the program. When determining the axle distances, we can enter the height of the building together if we want. After this stage, our floor plan has been formed except for the columns. In order to define our columns, first we must define the properties of our materials. The materials we use in this model are concrete and steel. We will use the concrete for columns, beams and floors, while the steel will be used for the reinforcement of these elements. We use C25 concrete for concrete. This concrete is resistant to pressure under 25 MPa. We preferred S420 material for steel fittings. You can see the material properties in more detail below.

The screenshot shows the 'Material Property Data' dialog box for a concrete material. The 'General Data' section includes 'Material Name and Display Color' (C25/30), 'Material Type' (Concrete), and 'Material Grade' (C25/30). The 'Weight and Mass' section shows 'Weight per Unit Volume' (25) and 'Mass per Unit Volume' (2.5493). The 'Isotropic Property Data' section includes 'Modulus Of Elasticity, E' (30000000), 'Poisson, U' (0.2), 'Coefficient Of Thermal Expansion, A' (1.000E-05), and 'Shear Modulus, G' (12500000). The 'Other Properties For Concrete Materials' section includes 'Specified Concrete Compressive Strength, Fc' (25000), 'Expected Concrete Compressive Strength' (25000), and a checkbox for 'Lightweight Concrete'. The 'Switch To Advanced Property Display' checkbox is unchecked. The 'OK' and 'Cancel' buttons are at the bottom.

Figure 21: Properties of Concrete

The screenshot shows the 'Material Property Data' dialog box for a steel material. The 'General Data' section includes 'Material Name and Display Color' (S420) and 'Material Type' (Rebar). The 'Weight and Mass' section shows 'Weight per Unit Volume' (0) and 'Mass per Unit Volume' (0). The 'Uniaxial Property Data' section includes 'Modulus Of Elasticity, E' (2.000E+08), 'Poisson, U' (0), 'Coefficient Of Thermal Expansion, A' (1.200E-05), and 'Shear Modulus, G'. The 'Other Properties For Rebar Materials' section includes 'Minimum Yield Stress, Fy' (420000), 'Minimum Tensile Stress, Fu' (500000), 'Expected Yield Stress, Fye' (420000), and 'Expected Tensile Stress, Fue' (500000). The 'Switch To Advanced Property Display' checkbox is unchecked. The 'OK' and 'Cancel' buttons are at the bottom.

Figure 22: Properties of Steel

There are some types of damaged concrete that we have defined for use in the later stages of our project. We have 10 types of damaged concrete calculated by various percentages. We have obtained these damaged concretes by reducing the elasticity modulus of the concrete. to give an example, the elasticity modulus of healthy concrete is 30,000,000 Pa while the elasticity modulus of concrete is 9,000,000 Pa which is 70% damaged. You can see some material properties of damaged concrete at the below.

The screenshot shows the 'Material Property Data' dialog box for a material named 'DAM_30_conc'. The material type is 'Concrete' and the grade is 'C25/30'. The units are set to 'KN, m, C'. The isotropic property data is as follows:

Property	Value
Modulus Of Elasticity, E	21000000
Poisson, U	0.2
Coefficient Of Thermal Expansion, A	1.000E-05
Shear Modulus, G	8750000

Other properties for concrete materials include a specified compressive strength of 25000 and an expected compressive strength of 25000. The 'Lightweight Concrete' checkbox is unchecked.

Figure 23: Properties of 30% Damaged Concrete

The screenshot shows the 'Material Property Data' dialog box for a material named 'DAM_70_conc'. The material type is 'Concrete' and the grade is 'C25/30'. The units are set to 'KN, m, C'. The isotropic property data is as follows:

Property	Value
Modulus Of Elasticity, E	9000000
Poisson, U	0.2
Coefficient Of Thermal Expansion, A	1.000E-05
Shear Modulus, G	3750000

Other properties for concrete materials include a specified compressive strength of 25000 and an expected compressive strength of 25000. The 'Lightweight Concrete' checkbox is unchecked.

Figure 24: Properties of 70% Damaged Concrete

After defining the material properties, the next step is to define the column, beam, and slab properties. Since the beams and floors are not different, we can identify them in a short time. In other words, all beams and all slabs have the same properties. But since we have 6 kinds of columns, it takes a little longer to identify the columns. The dimensions of the columns are different, as well as the number and arrangement of the bars of the placed inside the columns. Depending on this, sometimes stirrup arrangements can be different. You can see a diagram of the placement of the reinforcement bars below.

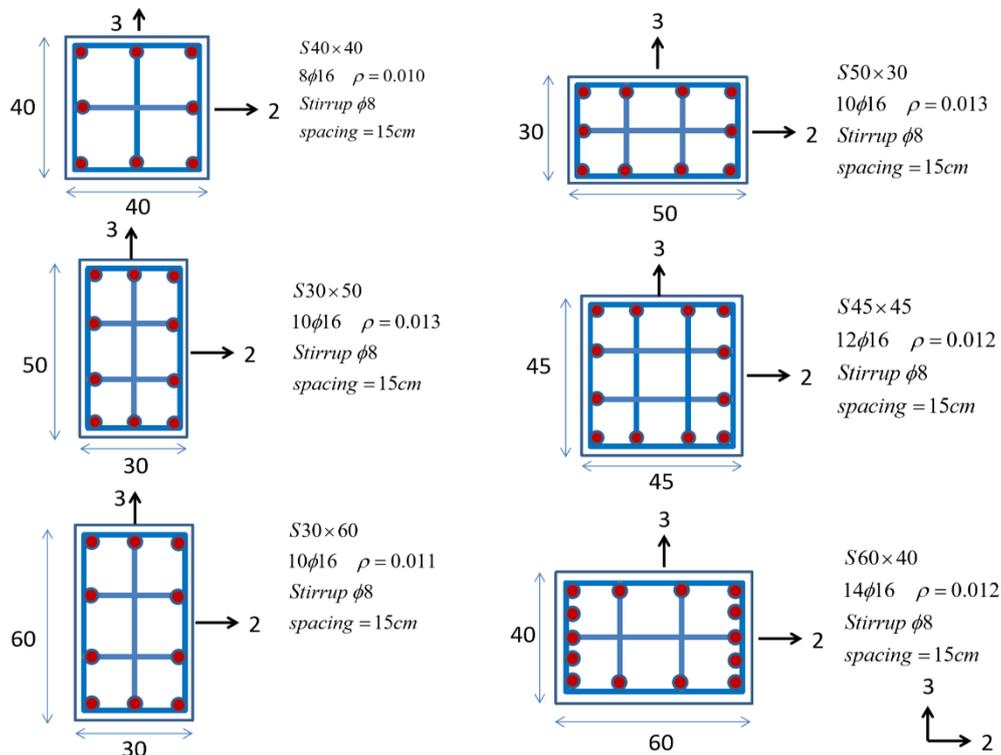


Figure 25: Arrangement of Steel Bars

Up to this point we have defined our material properties and building elements. We can imagine our building as a one-story structure, considering the extent to which we have come now. In this program, we get the chance to examine the structure more easily by showing each of the building elements in a different color. as you can see in the photo below, all the columns are in different colors, as well as different colors in the beams and slabs. Thanks to the different colors, a beautiful visual image is created, and we can make the process easier to examine.

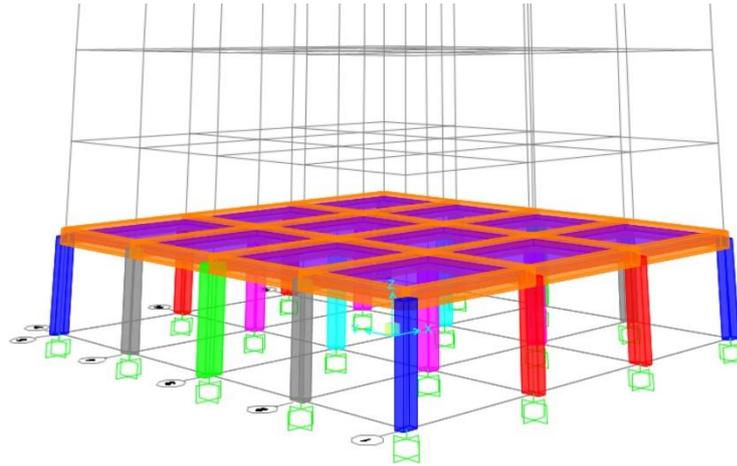


Figure 26: One Story of Model

After this step, our job is easy. At this point, our path splits in two, but the end of the road leads to the same place. There is no difficulty in either way. But one way is easier than the other. The first way will be to identify the elements one by one in the other floors of our building. Assuming our building has 16 floors, that means repeating this process 16 times. Although this preference is not often preferred, but we modeled the rest of our building with this way. Another way is to use the program's feature to copy as much as we want. Thanks to this convenience, we can build our model in seconds. You can see the latest model of our building below.

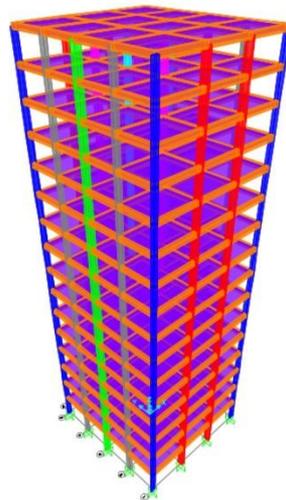


Figure 27: Model of Structure

2.3 SAP2000 Values Analyzing and Excel Graphics

Joint	Health	Mode1_X_0	Mode1_X_10	Mode1_X_20	Mode1_X_30	Mode1_X_40	Mode1_X_50	Mode1_X_60	Mode1_X_70	Mode1_X_80	Mode1_X_90	Mode1_X_100
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
2	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0014
41	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0037	0,0036	0,0034
61	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0063	0,0063	0,0063	0,0062	0,0062	0,0059
81	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0085	0,0083
101	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0109	0,0106
121	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0132	0,0130
141	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0154	0,0152
161	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0175	0,0173
181	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0195	0,0195	0,0195	0,0193
201	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0213	0,0213	0,0212
221	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0229
241	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245
261	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0258
281	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0270
301	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0277	0,0279
321	0,0281	0,0281	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0283	0,0287

Table 2: Displacement of 3rd floor in Mode 1 – X Direction

Joint	Mode1_Y_0	Mode1_Y_0	Mode1_Y_10	Mode1_Y_20	Mode1_Y_30	Mode1_Y_40	Mode1_Y_50	Mode1_Y_60	Mode1_Y_70	Mode1_Y_80	Mode1_Y_90	Mode1_Y_100
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
2	0,0016	0,0016	0,0016	0,0016	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0013
41	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0037	0,0037	0,0037	0,0036	0,0033
61	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0060	0,0056
81	0,0085	0,0085	0,0085	0,0085	0,0085	0,0085	0,0085	0,0085	0,0085	0,0084	0,0083	0,0079
101	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0107	0,0107	0,0103
121	0,0131	0,0131	0,0131	0,0131	0,0131	0,0131	0,0131	0,0131	0,0131	0,0130	0,0129	0,0126
141	0,0153	0,0153	0,0153	0,0153	0,0153	0,0153	0,0153	0,0153	0,0153	0,0152	0,0151	0,0148
161	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0173	0,0173	0,0170
181	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0193	0,0193	0,0190
201	0,0213	0,0213	0,0213	0,0212	0,0212	0,0212	0,0212	0,0212	0,0212	0,0212	0,0212	0,0210
221	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0229	0,0228
241	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0244	0,0244	0,0244	0,0244
261	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0259
281	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0270	0,0272
301	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0279	0,0280	0,0283
321	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0286	0,0286	0,0287	0,0293

Table 3: Displacement of 3rd floor in Mode 1 – Y Direction

In the light of current developments in modal testing and signal processing, the vibration-based methods have become the most promising non-destructive damage detection technique [13]. The modal analysis or mode-superposition method is a linear dynamic response procedure that evaluates and overlaps free vibration mode shapes to characterize displacement models. Mode shapes define configurations in which a structure will naturally be displaced [14]. Along with the analyses, in the table above, we determined the displacement values in the corner columns by making vibration in the simulation and by eigen value analysis, which we designed in the SAP2000 program, and turned it into an excel table. In this section, we continued our work only according to the mode 1 damage rate and gradually increased this rate 10 times, provided that the amount of increase was 10%. The sensitivity of the mode shapes to damage also increases with mode number, as the mode shapes corresponding to higher frequencies, contain

more local deformation. Mode 1 is a global mode and therefore its shape is insensitive to damage [15].

Joint	Health	Mode1_X_0	Mode1_X_10	Mode1_X_20	Mode1_X_30	Mode1_X_40	Mode1_X_50	Mode1_X_60	Mode1_X_70	Mode1_X_80	Mode1_X_90	Mode1_X_100
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
2	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015	0,0015
41	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0037
61	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0061	0,0060
81	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0086	0,0085	0,0083
101	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0110	0,0109	0,0109	0,0109	0,0108	0,0106
121	0,0133	0,0133	0,0133	0,0133	0,0133	0,0133	0,0132	0,0132	0,0132	0,0132	0,0131	0,0128
141	0,0155	0,0155	0,0155	0,0155	0,0155	0,0155	0,0154	0,0154	0,0154	0,0154	0,0153	0,0149
161	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0176	0,0175	0,0172
181	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0196	0,0195	0,0195	0,0193
201	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0214	0,0213	0,0212
221	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0230	0,0229
241	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245
261	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0257	0,0258	0,0258	0,0259
281	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0268	0,0271
301	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0276	0,0277	0,0280
321	0,0281	0,0281	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0282	0,0283	0,0287

Table 4: Displacement of 8th floor in Mode 1 – X Direction

Joint	Mode1_Y_0	Mode1_Y_10	Mode1_Y_20	Mode1_Y_30	Mode1_Y_40	Mode1_Y_50	Mode1_Y_60	Mode1_Y_70	Mode1_Y_80	Mode1_Y_90	Mode1_Y_100
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
2	0,0016	0,0016	0,0016	0,0016	0,0016	0,0016	0,0016	0,0015	0,0015	0,0015	0,0015
41	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0038	0,0037
61	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0061	0,0060
81	0,0085	0,0085	0,0085	0,0085	0,0085	0,0084	0,0084	0,0084	0,0084	0,0084	0,0083
101	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0108	0,0107	0,0107	0,0107	0,0106
121	0,0131	0,0131	0,0131	0,0131	0,0131	0,0130	0,0130	0,0130	0,0130	0,0129	0,0128
141	0,0153	0,0153	0,0153	0,0153	0,0153	0,0152	0,0152	0,0152	0,0152	0,0151	0,0150
161	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0174	0,0173	0,0173
181	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0194	0,0193
201	0,0213	0,0213	0,0213	0,0213	0,0213	0,0213	0,0213	0,0212	0,0212	0,0212	0,0212
221	0,0229	0,0229	0,0229	0,0229	0,0229	0,0230	0,0230	0,0230	0,0229	0,0229	0,0229
241	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245	0,0245
261	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0258	0,0259
281	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0269	0,0270	0,0270
301	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0278	0,0279	0,0279	0,0280
321	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0285	0,0286	0,0286	0,0287

Table 5: Displacement of 8th floor in Mode 1 – Y Direction

When we compare the displacement values of the 3rd and 8th floors, we see that some values are the same and some values are different. The reason for this is due to the flexibility of our model. Even if the displacement of the columns exposed to vibration in the same axis is very small, when we look upwards, we can observe that the displacement rate during vibration increases. As a result, we will use these displacement data to find tangent values. For this reason, displacement analysis has a very important point in this simulation.

After analyzing the displacement values separately from the SAP2000 program, we calculate the tangent values. In this calculation, we make it according to the following formula and create separate excel tables for two floors and two axes.

$$\text{Tangent} = \frac{\text{Difference of Mode1_axis_ (damage ratio) between 2 joints}}{\text{Difference of health between 2 joints}}$$

Figure 28: Tangent formula on displacement values

Calculation example from excel sheet from Displacement of 3rd floor in Mode 1 – X Direction (Figure 6)

$$\frac{\text{Mode1_X_0 (joint 2) - Mode1_X_0 (joint1)}}{\text{Health of joint 2 - Health of joint 1}}$$

Figure 29: Tangent Formula Example

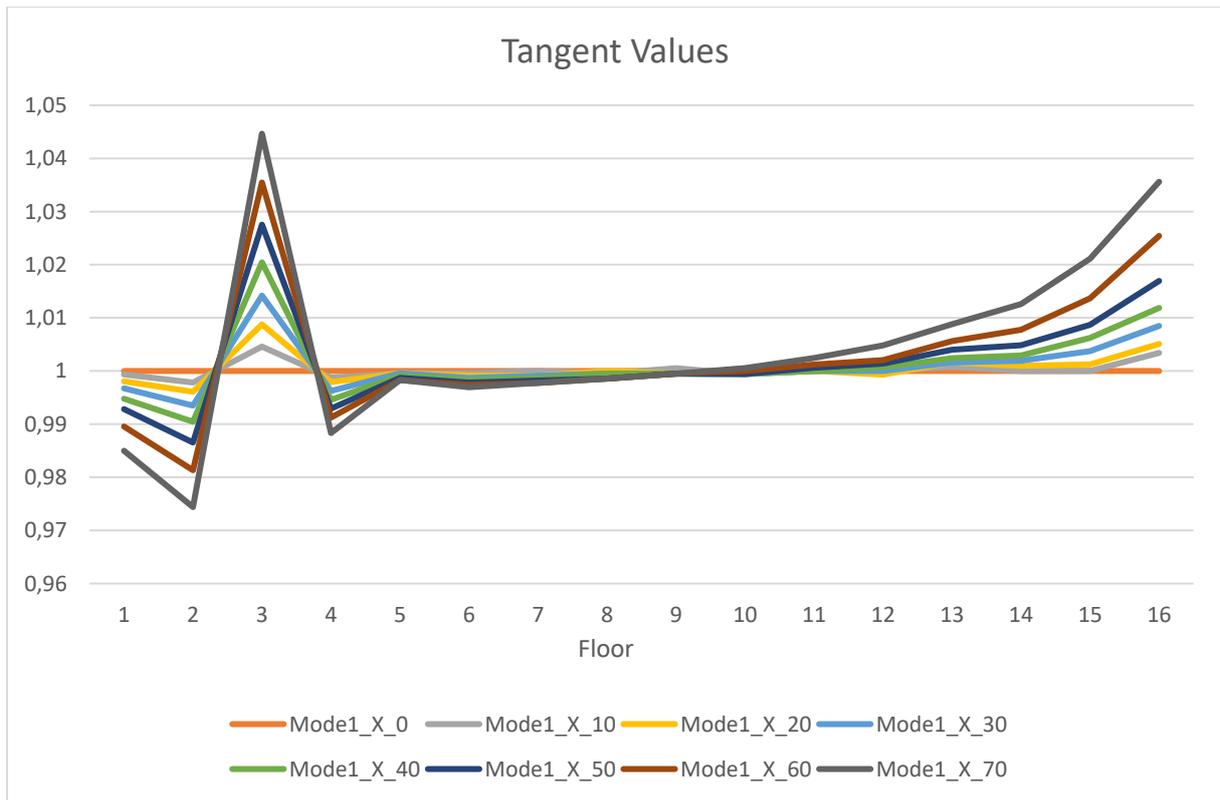


Figure 30: Tangent values of 3rd floor in X direction

In the graph of the tangent values on modal structure, which is designed by SAP2000, we see a clear break on the 3rd floor. This break signals that there is a problem in this column on the 3rd floor. When the tangent values that move in a straight line after the 5th floor go to the upper floors, it gets a slight curve.

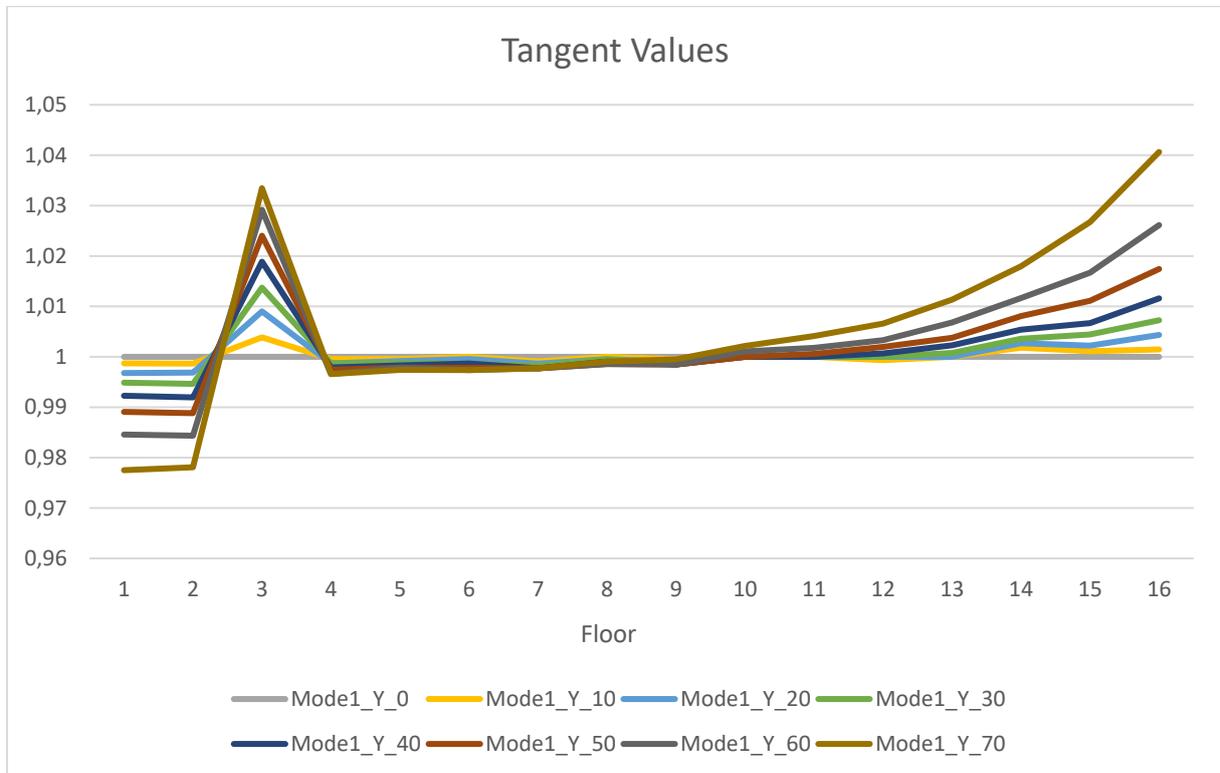


Figure 31: Tangent values of 3rd floor in Y direction

In the graph of the tangent values on modal structure, which is designed by SAP2000, we see a slight break on the 3rd floor. This break signals that there is a problem in this column on the 3rd floor. When the tangent values that move in a straight line after the 4th floor go to the upper floors, it gets a slight curve. But in general, we can observe that the vibration on the Y axis is better than the X axis.

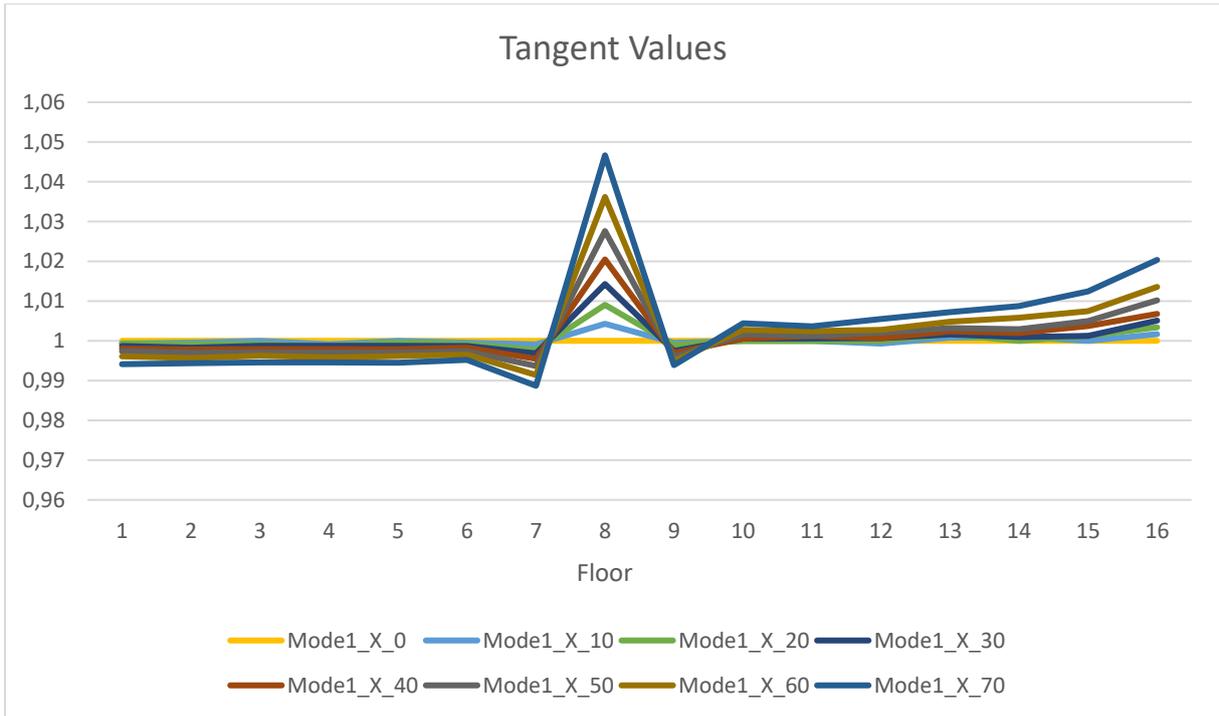


Figure 32: Tangent values of 8th floor in X direction

In the graph of the tangent values on modal structure, which is designed by SAP2000, we see a break when we assume 60% damaged column on the 8th floor. This break signals that there is a problem in this column on the 8th floor. The tangent values, which progress in a straight line from the ground floor to the 6th floor, increase partially according to the rates on the lower floor after the 8th floor column break.

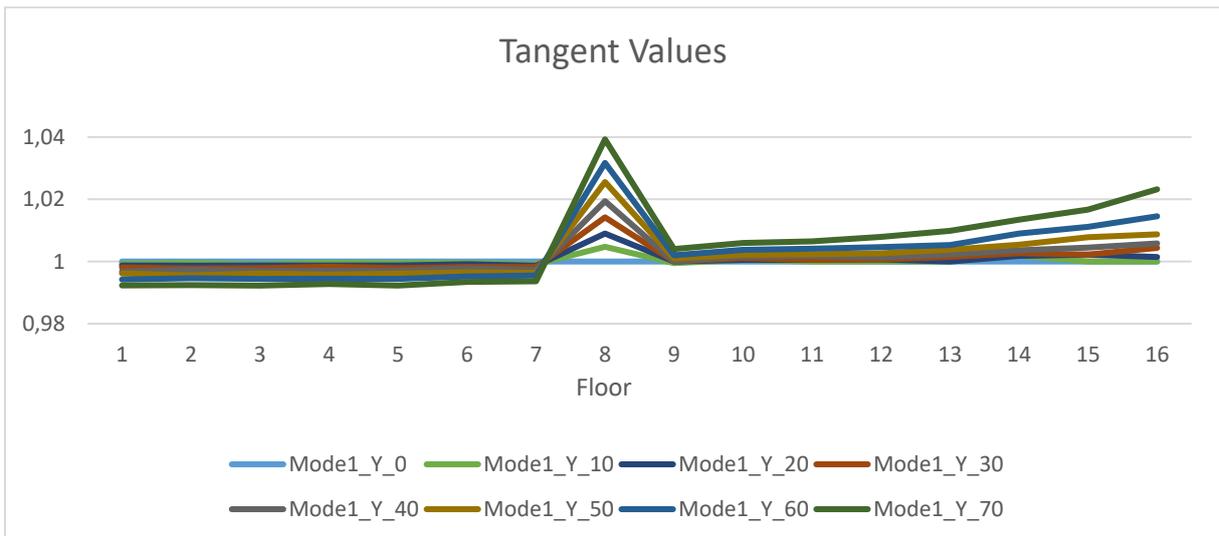


Figure 33: Tangent values of 8th floor in Y direction

In the graph of the tangent values on the Y axis of the 8th floor, we see a break in case we assume a 60% damaged column on the 8th floor. As in the X axis, the tangent values, which progress in a straight line from the ground floor to the 6th floor on the Y axis, partially increase after breaking the 8th floor compared to the rates on the lower floor, but the damage rate is 100%, which leaves a serious impact on the column. We observe that the other floors change their tangent values seriously.

$$\frac{\text{Arctan}(x)}{\pi * 180} = y$$

Figure 34: Arctangent formula

The X value in the formula represents the value in the tangent table. Y value shows the value in the absolute angle table.

Floor	Mode1_X_0	Mode1_X_10	Mode1_X_20	Mode1_X_30	Mode1_X_40	Mode1_X_50	Mode1_X_60	Mode1_X_70	Mode1_X_80	Mode1_X_90	Mode1_X_100
1	45	44,98	44,94	44,91	44,85	44,79	44,70	44,57	44,34	43,86	42,03
2	45	44,94	44,89	44,81	44,73	44,61	44,46	44,26	43,96	43,38	41,45
3	45	45,13	45,25	45,40	45,58	45,78	46,00	46,25	46,50	46,72	46,22
4	45	44,96	44,94	44,89	44,84	44,80	44,75	44,66	44,59	44,52	44,57
5	45	44,99	44,99	44,99	44,98	44,96	44,95	44,95	44,94	44,95	45,10
6	45	44,99	44,98	44,96	44,95	44,94	44,93	44,91	44,91	44,93	45,12
7	45	45,00	44,97	44,97	44,96	44,95	44,94	44,94	44,94	44,97	45,25
8	45	44,99	45,00	44,99	44,99	44,96	44,96	44,96	44,97	45,05	45,42
9	45	45,01	44,99	44,99	44,99	44,99	44,99	44,99	45,03	45,12	45,63
10	45	44,98	45,00	44,98	44,98	44,98	45,00	45,02	45,06	45,24	45,90
11	45	45,00	45,00	45,00	45,00	45,02	45,03	45,07	45,16	45,36	46,28
12	45	45,00	44,98	45,00	45,02	45,04	45,06	45,14	45,26	45,55	46,76
13	45	45,02	45,05	45,05	45,07	45,11	45,16	45,25	45,41	45,84	47,46
14	45	45,00	45,03	45,06	45,08	45,14	45,22	45,36	45,63	46,20	48,39
15	45	45,00	45,04	45,11	45,18	45,25	45,39	45,60	45,98	46,79	49,84
16	45	45,10	45,15	45,24	45,34	45,48	45,72	46,00	46,56	47,81	52,14

Table 6: Absolute angles of 3rd floor in X direction

Floor	Mode1_Y_0	Mode1_Y_10	Mode1_Y_20	Mode1_Y_30	Mode1_Y_40	Mode1_Y_50	Mode1_Y_60	Mode1_Y_70	Mode1_Y_80	Mode1_Y_90	Mode1_Y_100
1	45	44,96	44,91	44,85	44,78	44,69	44,55	44,35	44,03	43,33	40,61
2	45	44,96	44,91	44,85	44,77	44,68	44,55	44,37	44,04	43,37	40,71
3	45	45,11	45,26	45,39	45,54	45,68	45,82	45,94	46,03	45,92	44,72
4	45	44,99	44,96	44,96	44,94	44,93	44,90	44,90	44,90	44,90	45,05
5	45	44,99	44,98	44,96	44,95	44,94	44,94	44,93	44,93	44,99	45,25
6	45	45,00	44,99	44,96	44,96	44,94	44,92	44,92	44,94	45,00	45,34
7	45	44,97	44,96	44,95	44,94	44,94	44,94	44,94	44,96	45,04	45,48
8	45	45,00	44,99	44,99	44,97	44,96	44,96	44,97	45,01	45,14	45,68
9	45	44,99	44,97	44,96	44,96	44,96	44,96	44,99	45,06	45,23	45,95
10	45	45,00	45,00	45,00	45,00	45,00	45,03	45,06	45,14	45,38	46,34
11	45	45,00	45,00	45,00	45,00	45,02	45,05	45,12	45,24	45,55	46,79
12	45	44,98	45,00	45,00	45,02	45,06	45,09	45,19	45,38	45,78	47,41
13	45	45,00	45,00	45,02	45,06	45,11	45,19	45,32	45,56	46,13	48,25
14	45	45,05	45,08	45,10	45,15	45,23	45,33	45,51	45,86	46,60	49,38
15	45	45,03	45,06	45,13	45,19	45,32	45,47	45,76	46,25	47,27	51,00
16	45	45,04	45,12	45,21	45,33	45,49	45,74	46,14	46,81	48,33	53,29

Table 7: Absolute angles of 3rd floor in Y direction

The table of absolute tangent values has almost the same graph as the table of tangent values because the increase and decrease amounts of the results due to the formula are the same. The importance of these tables for our simulation is that it enables us to find the relative angle. The X and Y axes on the 3rd and 8th floors must have a relative angle for each damaged column value of Mode 1.

Floor	Mode1_X_0	Mode1_X_10	Mode1_X_20	Mode1_X_30	Mode1_X_40	Mode1_X_50	Mode1_X_60	Mode1_X_70	Mode1_X_80	Mode1_X_90	Mode1_X_100
1	45	44,98	44,98	44,96	44,94	44,93	44,89	44,83	44,77	44,62	43,93
2	45	44,99	44,98	44,95	44,94	44,91	44,88	44,84	44,76	44,62	43,94
3	45	45,00	44,98	44,96	44,94	44,92	44,89	44,84	44,77	44,63	43,93
4	45	44,98	44,96	44,96	44,94	44,92	44,88	44,84	44,76	44,61	43,94
5	45	45,00	44,99	44,96	44,94	44,91	44,89	44,84	44,78	44,63	43,94
6	45	44,99	44,98	44,96	44,95	44,93	44,90	44,86	44,80	44,66	44,01
7	45	44,97	44,94	44,91	44,87	44,82	44,75	44,67	44,56	44,36	43,63
8	45	45,12	45,26	45,41	45,58	45,78	46,02	46,31	46,65	47,10	47,75
9	45	44,99	44,97	44,93	44,91	44,88	44,85	44,82	44,84	44,96	45,99
10	45	45,00	45,00	45,02	45,02	45,05	45,08	45,13	45,20	45,42	46,71
11	45	45,00	45,00	45,02	45,03	45,03	45,07	45,10	45,21	45,48	46,92
12	45	44,98	45,00	45,02	45,02	45,06	45,08	45,16	45,27	45,57	47,27
13	45	45,02	45,05	45,05	45,07	45,09	45,14	45,21	45,34	45,73	47,77
14	45	45,03	45,00	45,03	45,06	45,08	45,17	45,25	45,47	45,90	48,42
15	45	45,00	45,04	45,04	45,11	45,14	45,21	45,35	45,60	46,22	49,39
16	45	45,05	45,10	45,15	45,19	45,29	45,39	45,58	45,91	46,74	51,02

Table 8: Absolute angles of 8th floor in X direction

Floor	Mode1_Y_0	Mode1_Y_10	Mode1_Y_20	Mode1_Y_30	Mode1_Y_40	Mode1_Y_50	Mode1_Y_60	Mode1_Y_70	Mode1_Y_80	Mode1_Y_90	Mode1_Y_100
1	45	44,98	44,96	44,94	44,91	44,89	44,83	44,78	44,69	44,48	43,43
2	45	44,99	44,96	44,94	44,92	44,87	44,85	44,78	44,69	44,48	43,41
3	45	44,98	44,96	44,94	44,91	44,89	44,84	44,78	44,68	44,49	43,42
4	45	44,99	44,96	44,95	44,91	44,88	44,84	44,79	44,69	44,48	43,44
5	45	44,99	44,96	44,94	44,91	44,89	44,84	44,78	44,69	44,50	43,45
6	45	44,99	44,97	44,95	44,94	44,90	44,86	44,81	44,72	44,53	43,53
7	45	44,97	44,96	44,95	44,92	44,90	44,87	44,82	44,74	44,56	43,65
8	45	45,14	45,26	45,40	45,55	45,72	45,89	46,10	46,34	46,63	47,09
9	45	44,99	45,00	45,00	45,00	45,03	45,06	45,11	45,21	45,48	47,09
10	45	45,02	45,02	45,03	45,05	45,06	45,11	45,17	45,31	45,64	47,50
11	45	45,00	45,02	45,02	45,05	45,07	45,12	45,19	45,34	45,72	47,84
12	45	45,00	45,02	45,02	45,04	45,08	45,13	45,23	45,39	45,84	48,29
13	45	45,00	45,00	45,04	45,06	45,11	45,15	45,28	45,49	46,00	48,87
14	45	45,05	45,05	45,08	45,10	45,15	45,26	45,38	45,64	46,28	49,71
15	45	45,00	45,06	45,06	45,13	45,22	45,32	45,47	45,82	46,64	50,85
16	45	45,00	45,04	45,12	45,17	45,25	45,41	45,66	46,10	47,16	52,53

Table 9: Absolute angles of 8th floor in Y direction

The calculation of the relative angle is based on a simple mathematical operation. It is the difference between the desired value and the values of the previous floor to find the desired relative angle.

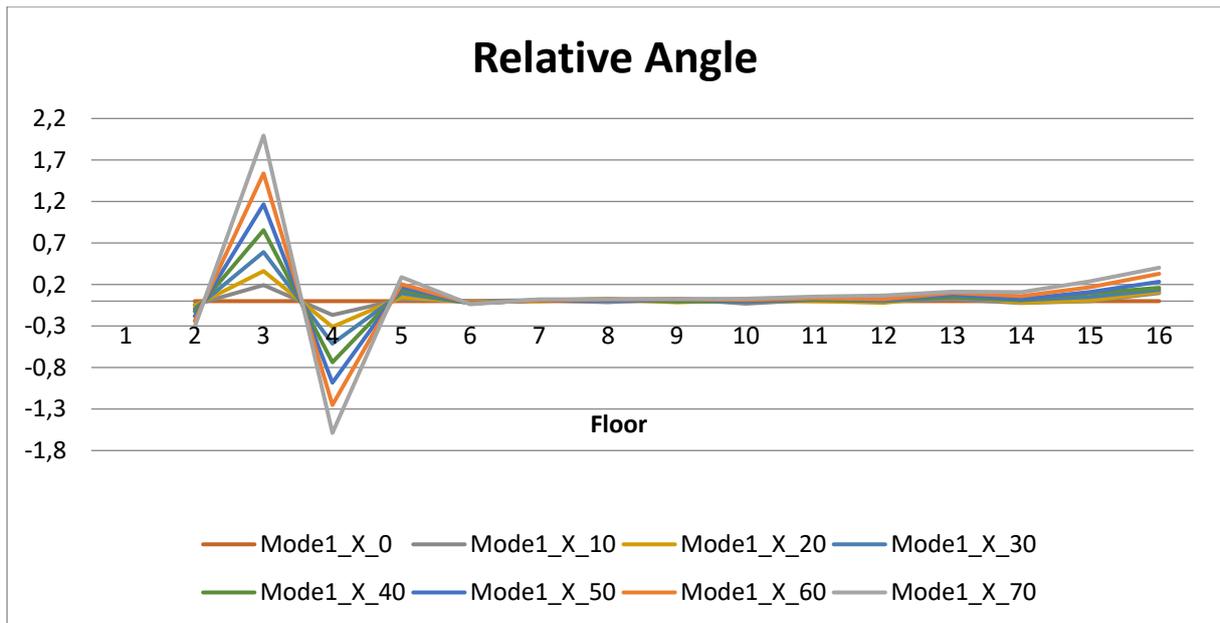


Figure 35: Relative angles of 3rd floor in X direction

In this section, relative angle values are tabulated in Excel and visualized as graphics. However, we can see in what floor there is a break. The relative angle differences between the 3rd and 4th floors are very different from the other floors and this value has increased as seen in the graph as the damage value of the particular column increases. This visible breakdown on the graph shows us that the breaks in the previous values of the simulation are similar and confirm those values.

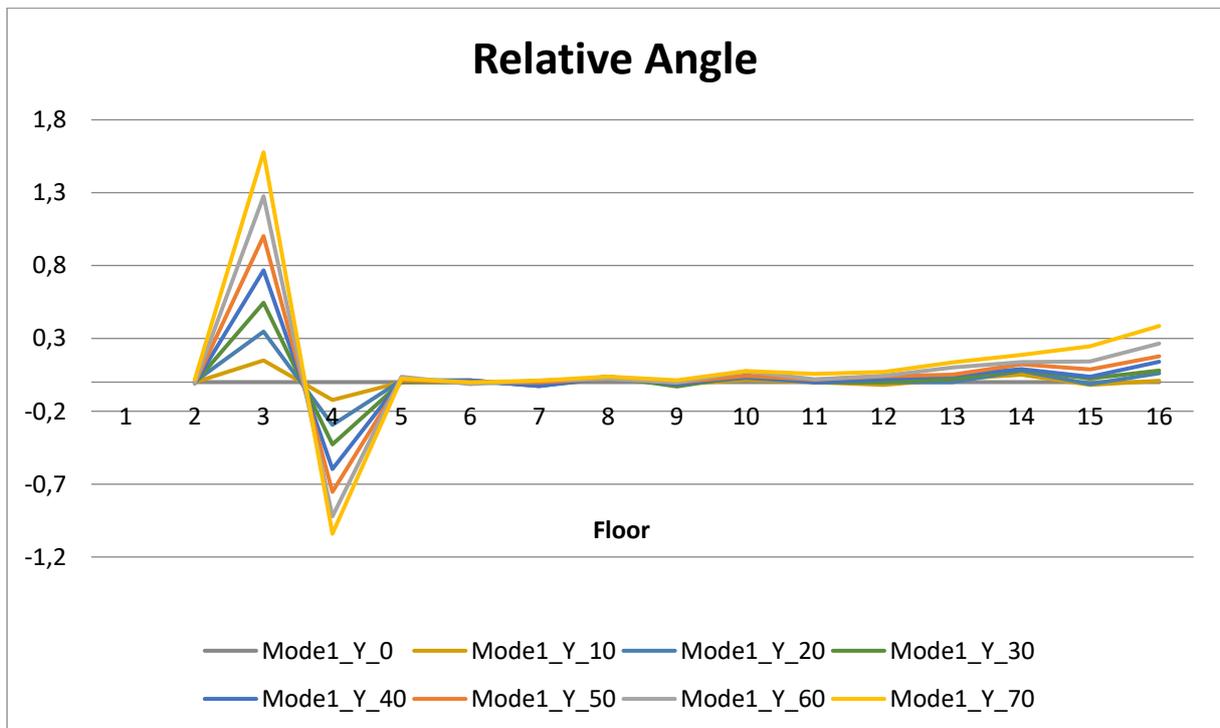


Figure 36: Relative angles of 3rd floor in Y direction

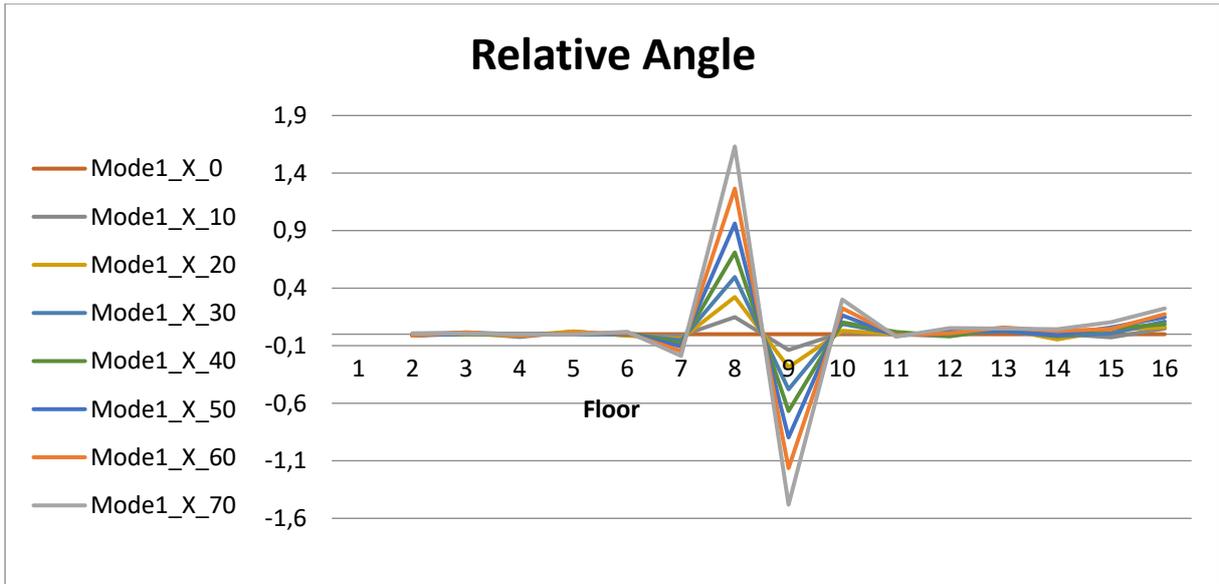


Figure 37: Relative angles of 8th floor in X direction

In this section, relative angle values are tabulated in excel and visualized as graphics. It can be seen where the gradually damaged floor is and how it has been broken, and these values can be compared with the values on the 3rd and 4th floors. The relative angle differences between the 8th and 9th floors differed significantly from other floors, and this value increased as seen in the graph as the damage value of the particular column increased. This apparent fault in the graph indicates that the breaks in the previous values of the simulation are similar and confirm these values.

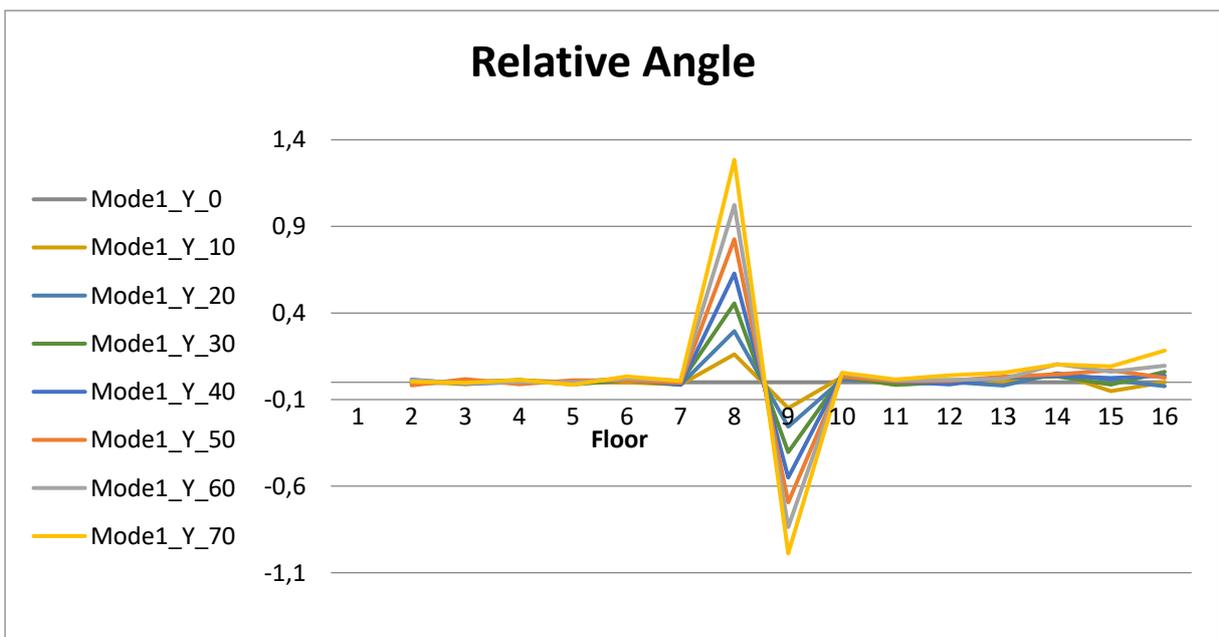


Figure 38: Relative angles of 8th floor in Y direction

2.4 Flow Chart for Damage Detection Through Dynamic Analysis

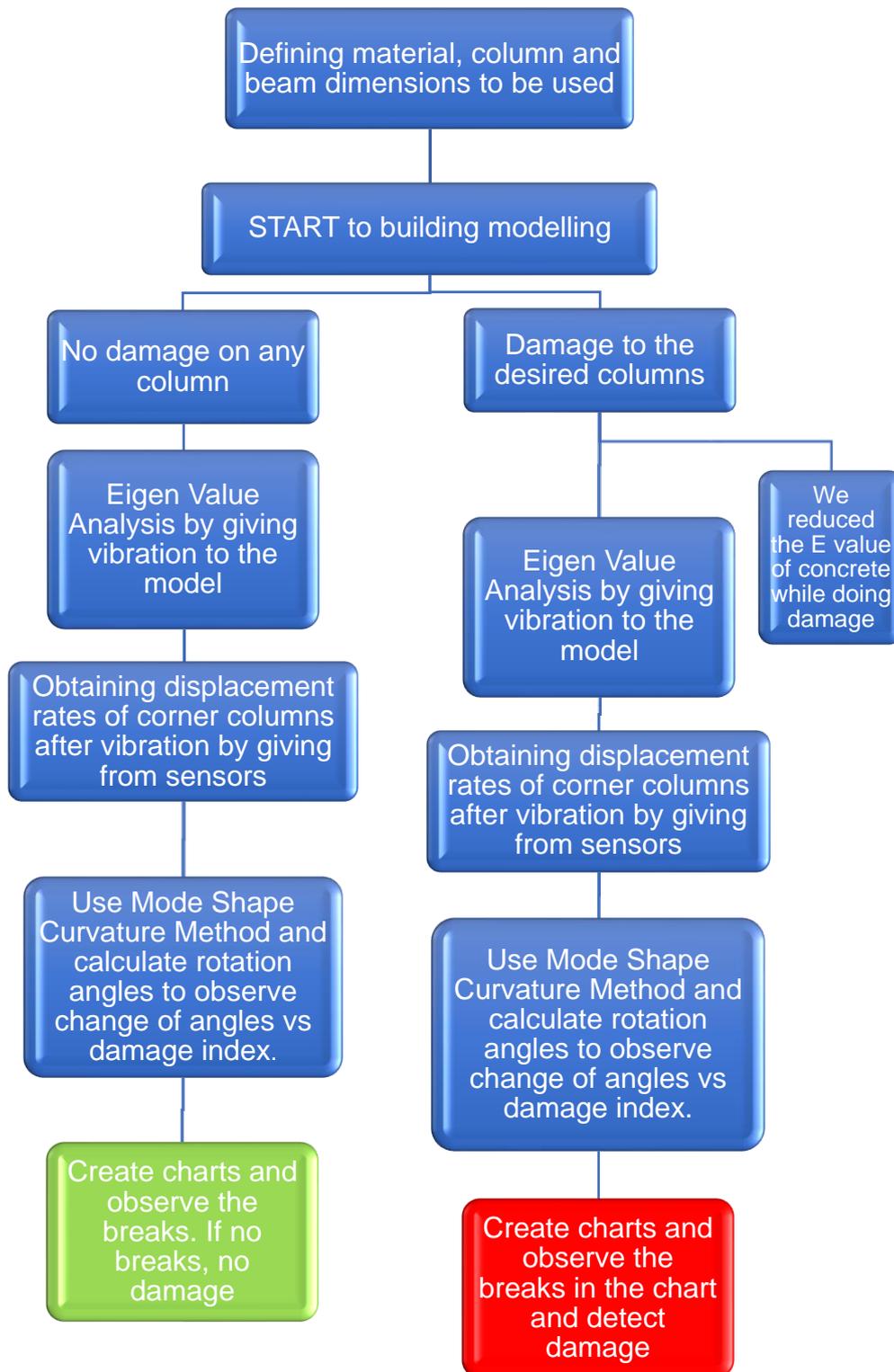


Figure 39: Flow Chart for damage detection through dynamic analysis

3. DISCUSSION

In this project, we have developed a method that allows us to find the damaged floor of the building with the rotation angles of the building. We damaged the building we designed to prove this method. The person to use this method did not know which floor was damaged. The displacement values which are taken from SAP2000 program shown in Table 1 were given to the person who will use the method. The rotation angles of the building were calculated with this displacement data. Table 2 were prepared with those rotation angles. Using the data in Table 2, the angle changes between the damaged building and the undamaged building were calculated. As shown in Table 3, in the damaged building number 1, a further change was observed in the rotation angles when passing from 5th Floor to 6th Floor, 6th Floor to 7th Floor, 12th Floor to 13th Floor and 13th Floor to 14th Floor. It's demonstrated us 6th and 13th floors have damaged. In the damaged building number 2, a further change was observed in the rotation angles when passing from 6th Floor to 7th Floor and 7th Floor to 8th Floor. It's demonstrated us 7th floor have damaged. It was observed that the correct results were obtained when we compared the results we obtained with the actual results. This proves the usability of this method.

Joint	Displacement of Healthy Building	Displacement of the Building with UNKNOWN Damaged	Displacement of the Building with UNKNOWN Damaged2
1	0,00000	0,00000	0,00000
2	0,00153	-0,00151	0,00152
41	0,00383	-0,00378	0,00379
61	0,00623	-0,00614	0,00616
81	0,00863	-0,00850	0,00853
101	0,01099	-0,01081	0,01087
121	0,01329	-0,01324	0,01313
141	0,01550	-0,01543	0,01547
161	0,01760	-0,01754	0,01756
181	0,01957	-0,01952	0,01954
201	0,02138	-0,02134	0,02137
221	0,02302	-0,02300	0,02302
241	0,02448	-0,02446	0,02449
261	0,02572	-0,02578	0,02575
281	0,02675	-0,02682	0,02680
301	0,02756	-0,02765	0,02763
321	0,02815	-0,02827	0,02824

Table 10: Joint Displacement of the Building

FLOOR	Rotation of the Building with ZERO Damaged	Rotation of the Building with UNKNOWN Damaged	Rotation of the Building with UNKNOWN Damaged2
FLOOR 1	45,00	-44,59	44,70
FLOOR 2	45,00	-44,57	44,69
FLOOR 3	45,00	-44,58	44,70
FLOOR 4	45,00	-44,60	44,69
FLOOR 5	45,00	-44,34	44,73
FLOOR 6	45,00	-46,60	44,46
FLOOR 7	45,00	-44,74	46,64
FLOOR 8	45,00	-45,11	44,82
FLOOR 9	45,00	-45,12	45,17
FLOOR 10	45,00	-45,16	45,19
FLOOR 11	45,00	-45,23	45,24
FLOOR 12	45,00	-45,18	45,27
FLOOR 13	45,00	-46,72	45,41
FLOOR 14	45,00	-45,28	45,50
FLOOR 15	45,00	-45,88	45,70
FLOOR 16	45,00	-46,33	46,10

Table 11: Rotation of the Building

FLOOR	Difference of the Rotation of the Building with ZERO Damaged	Difference of the Rotation of the Building with UNKNOWN Damaged	Difference of the Rotation of the Building with UNKNOWN Damaged2
FLOOR 1	0,00	0,00	0,00
FLOOR 2	0,00	0,01	-0,01
FLOOR 3	0,00	0,00	0,01
FLOOR 4	0,00	-0,02	-0,01
FLOOR 5	0,00	0,27	0,04
FLOOR 6	0,00	-2,26	-0,27
FLOOR 7	0,00	1,86	2,18
FLOOR 8	0,00	-0,37	-1,81
FLOOR 9	0,00	-0,01	0,35
FLOOR 10	0,00	-0,04	0,01
FLOOR 11	0,00	-0,07	0,05
FLOOR 12	0,00	0,05	0,03
FLOOR 13	0,00	-1,54	0,14
FLOOR 14	0,00	1,44	0,09
FLOOR 15	0,00	-0,60	0,21
FLOOR 16	0,00	-0,45	0,39

Table 12: Difference of the Rotation of the Building

4.CONCLUSION

In final result of this project, we see that when we damage the building by reducing the Modules of elasticity, the damage values that we gradually increase on the 3rd floor and the damage on the upper floors and the lower floors of the displacements caused by the damage values we give gradually on the 8th floor, we concluded that it would be different(mod shapes) . Similarly, when we give the rotation angle data, we came to the conclusion that which story the damage can be found on. Therefore, we came to the conclusion that we can reach healthy data with the help of the Program without experience on a real building.

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