Analytical Modal Analysis of RC Building Retrofitted with CFRP using Finite Element Method

Sertaç TUHTA[1], Furkan GÜNDAY[2]
[1,2]*Department of Civil Engineering, Ondokuz Mayis University, Turkey*

***Abstract*—Many buildings in developing countries around the world are constantly facing earthquake effects. Against these effects, existing buildings need to be strengthened. In the last 20 years, fabrics reinforced with fiber reinforced polymer (FRP) have become a common material used to strengthen reinforced concrete buildings. In our country, mostly column and beam reinforcement are made. This is because the cost of this method is lower than that of using FRP. However, reinforcement studies with FRP (fiber reinforced polymer) composites have started to be implemented quite frequently in our country. These fabrics with high fiber strength provide great benefits in terms of modal parameters. CFRP is a FRP composite type. In this study, the slabs of an 11-storey reinforced concrete building were covered with 1 mm CFRP and analytical analysis was done using the finite element method. The differences between modal parameters of the concrete chimney and CFRP reinforced concrete chimney were compared. These modal parameters are period and mode shapes. The first 5 modes of the situation with and without CFRP were examined with finite element method. A difference of 12.19% - 32.17% was observed in the periods of the first 5 modes. CFRP fabrics are one of the most effective materials in strengthening all kinds of reinforced concrete buildings.**

***Keywords*—Modal Analysis, CFRP, Finite Element Method, RC Building**

I. INTRODUCTION

FRP means fiber reinforcement polymer. FRP's characteristic features determined relatively with 50 years' experience in some sectors (automotive, space, engineering, aviation). FRP's are in the fiber composite class at classification. Glass, carbon, aramid, basalt etc. which are FRP's raw materials are produced with mixing the fiber and resin. Fiber Reinforcement Polymers are the last technological material that is used at some industrial areas. Due to high resistance and not causing an extra load they are started to be used at civil engineering area. In test, columns with FRP gas damped more energy and had more displacement against to remaining seismic and repeat load. Beside the strengthening FRP are applied for protecting band and resistance that become because of corrosion. FRP black the relation of concrete, steel and resin with air. It doesn't give permission to be formed steam and diffusion and it protect the materials from acid and alkalis. CFRP materials compare to the other FRP materials, don't have resistance last when they are with alkalis for a long time. FRP productions are perfect materials for protecting the constructions from bomb and industrial accidents. This application requires special design that is made from different fiber and resin. The tests that are made in made in lost years help for determining the physical and mechanical properties of the materials. And also, the FRP's advantages and disadvantages determined analysis principles and the reasons of carefully application. Lately, in our country these materials are started o be used. There is standard available, related with the strengthening constructions by using these materials. For this reason, it is important to be careful about the advantages and the disadvantages which the applications will bring about and points like the application conditions of the calculation principles.[9],[10],[11].

CFRP is used in many sectors due to its various advantages. Marine (ships, shipyards), electric-electronics (solar collectors, wind turbines), aircraft, cars, various products (sports equipment) and buildings (buildings, highways, bridges, harbours, waterways, water and solid waste recycling facilities, etc.) has been increasing its usage area in recent years. Its properties such as high strength / weight ratio, corrosion resistance, resistance to external influences (salt water, acid) and low thermal conductivity are effective in its use in the building industry. Our country is one of the countries in the active earthquake zone. It is very important to strengthen the buildings before the earthquake or to repair and strengthen them after the earthquake. There are many methods developed for repair and strengthening. These have their advantages and disadvantages. One of them is the reinforcement made with CFRP reinforcement material. CFRP (Carbon Fiber Reinforced Polymers) is a material that has been used in many countries around the world today.

Historical buildings are used in many areas, especially bridges. One of its most important features is that it can be applied while the building is in use, or the building can be opened for use shortly after it is applied. It does not impose an extra load on the structure and does not cause image distortion thanks to its thin structure.

Surface preparation is very important for CFRP materials. Surface preparation is very important for CFRP materials. In reinforced concrete structures, steel does not show different behaviour than peeling and concrete since it remains in the concrete. The most important problem in the application of CFRP in structures is the stripping of the material or separating the concrete by taking the cover layer.

Carbon Fiber Reinforced Polymers (CFRP), commonly used by FRP for reinforcement, are still tested in the experimental environment and the strengthening provided to masonry buildings is evaluated. In our thesis topic, we will try to get an idea by comparing the rigidity of the stacking dome. Considering that the tensile strength is high and there is not much extra load due to its lightness to the structure, it is thought that the stability will increase. Their resistance to environmental conditions provides an ideal protection for the element from external influences, especially moisture protection and corrosion. Considering that chimney height affects modal loads negatively in chimneys, it is evident that the ductility of the building will increase and affect their behaviour against earthquake loads positively. [12],[14].

II. DESCRIPTION OF CARBON FIBER REINFORCED POLYMER

CFRP fabrics are made ready for use on the job site. While epoxy is applied to the surface prepared area, CFRP fabric is pressed in a flat epoxy filled container. In order for the fabric and epoxy to form a composite material and move together, care should be taken that there is no air gap in the fabric. [6], [7], [14].

With CFRP fabrics (fig 1), the outer surfaces of concrete structures, arches, vaults and domes are wrapped in appropriate direction and width to increase their carrying capacity and ductility under existing loads. Preparation of the surface before the application of all dust and free of material to remove the material between CFRP fabric and structure that will affect the adherence of any dust particles should be careful. [6], [7], [14].

Fig. 1. CFRP fabric

Mechanical Properties of CFRP Material;

Mass and Weight of Material:

1- Unit Volume Weight = 1600,55 kgf / m3,

2- Unit Volume Mass = 163.15 kgf / m3.

Mechanical Properties of Material:

1- Elasticity Module:

E1 = 13766,17 kgf/mm2,

E2 = 13766,17 kgf/mm2,

E3 = 1019,7 kgf/mm2.

2- Poison Rate:

U12 = 0,3,

U13 = 0,3,

U23 = 0,022.

In this study, it was decided to use 1 mm CFRP fabric.SAP2000 package program was used in the implementation of CFRP.CFRP fabric is applied to slabs.

III. DESCRIPTION OF RC BUİLDİNG

The building consists of 11 stories with shear walls. The building was used as an apartment. The height of the stories is 2.75 meters, and the total height of the building is 27.5 meters. The total length of the RC building in the X direction is 27.9 meters. But this length is at floor level. On the upper floors, the length in X direction is 29.4 meters. In the building, in the direction of X, 1.5 meters climbs were made equal to the left and right sides. The total length of the RC building in the Y direction is 12.75 meters. This length from the ground to the upper floor in the Y direction is 12.75 meters. There are no climbs in the Y direction. The building was built according to TS 500 Turkish regulation.C30 was used as the concrete class in the building.S420 was used as steel reinforcement bar. The finite element model of the building was created with the help of the SAP2000 package program. The finite element model of the RC building is given in figure 2.

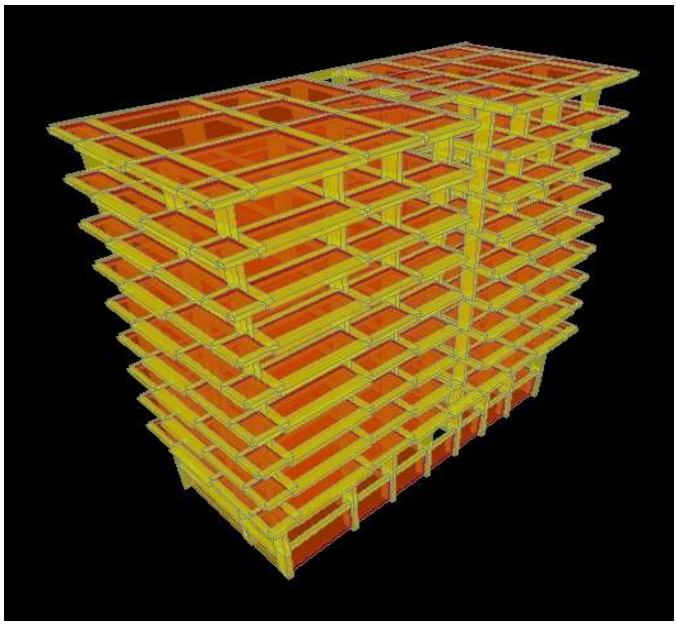

Fig 2. Finite element model of the RC building

IV. ANALYSİS OF RC BUİLDİNG

The finite element model of the RC building is shown in figure 2. The finite element model of the RC building given in Figure 2 is the current situation. In other words, it is not CFRP

reinforced. Reinforcement is planned on this concrete chimney model. CFRP fabric technique is used in this study as this reinforcement method. As a result of the modal analysis, the first 5 modes were taken into account in both cases. SAP2000 package program was used to obtain the analysis data.

Modal analysis results before applying CFRP to the RC Building are given in Table 1 and mode shapes given figure 3,4,5,6,7.

Table 1. Period of RC Building

Mode	1	2	3	4	5
Period (sec)	1.072	1.005	0.771	0.314	0.288

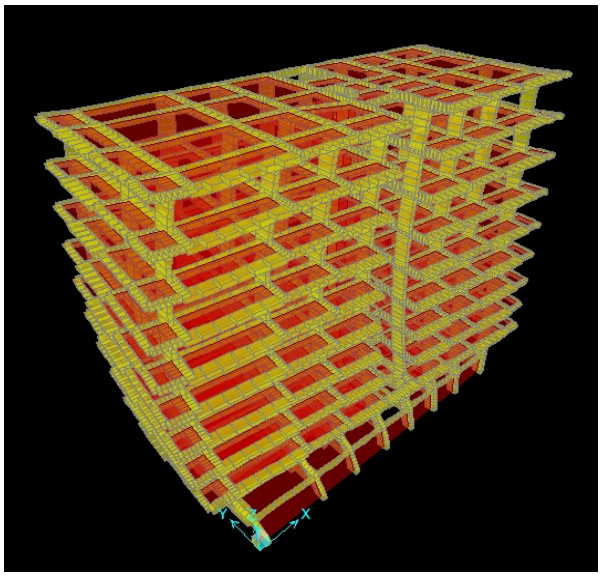

Fig 3. 1. Mode shape (T= 1.072 s)

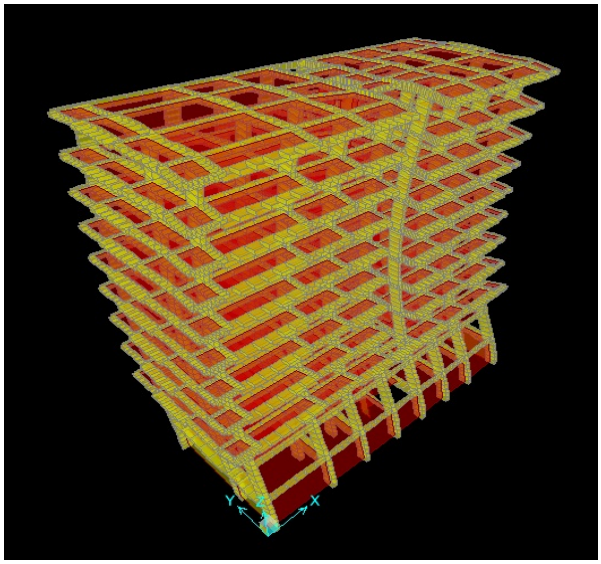

Fig 4. 2. Mode shape (T= 1.005 s)

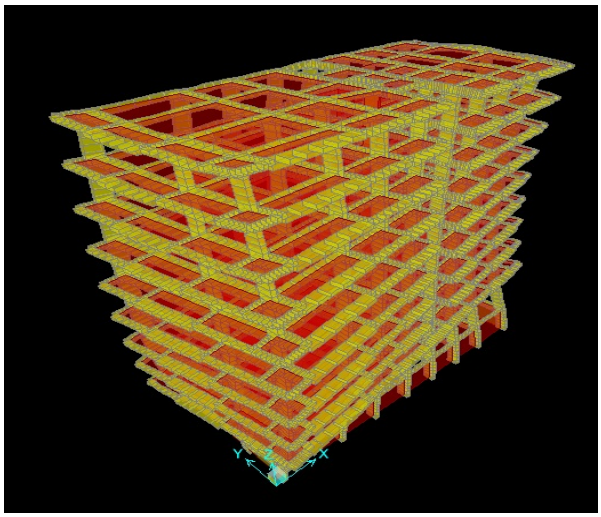

Fig 5. 3. Mode shape (T= 0771 s)

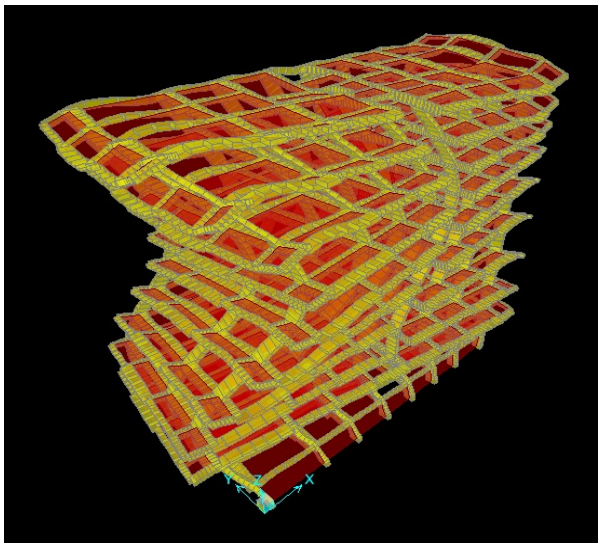

Fig 6. 4. Mode shape (T= 0.314 s)

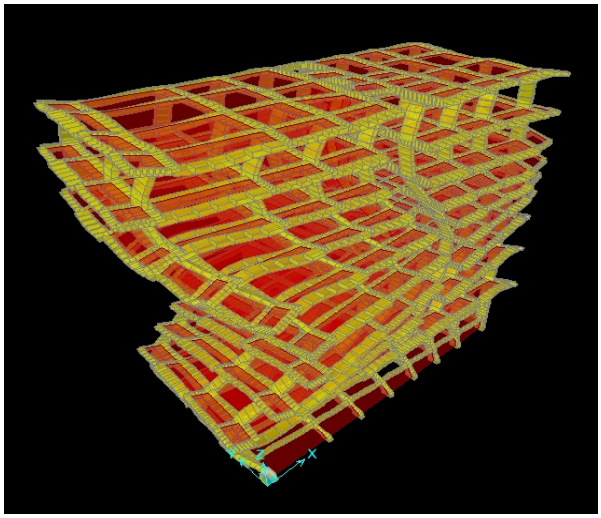

Fig 7.5. Mode shape (T= 0.288 s)

CFRP fabric technique is used in this study as this reinforcement method. CFRP fabric thickness is 1 mm. CFRP fabric is applied to slabs. SAP2000 package program was used to obtain the analysis data.

Modal analysis results after applying CFRP to the RC building are given in Table 2 and mode shapes given figure 8,9,10,11,12.

Table 2. Period of RC Building reinforcedwith CFRP

Mode	**1**	**2**	**3**	**4**	**5**
Period (sec)	0.940	0.838	0.677	0.213	0.196

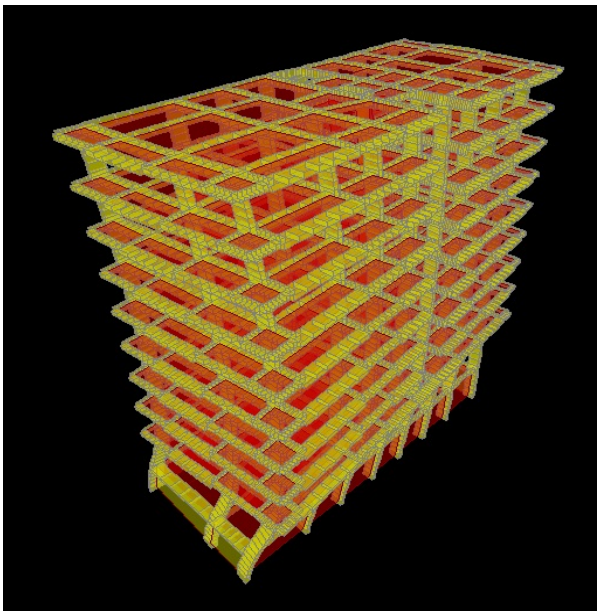

Fig 8. 1. Mode shape (*T*= 0.940 s)

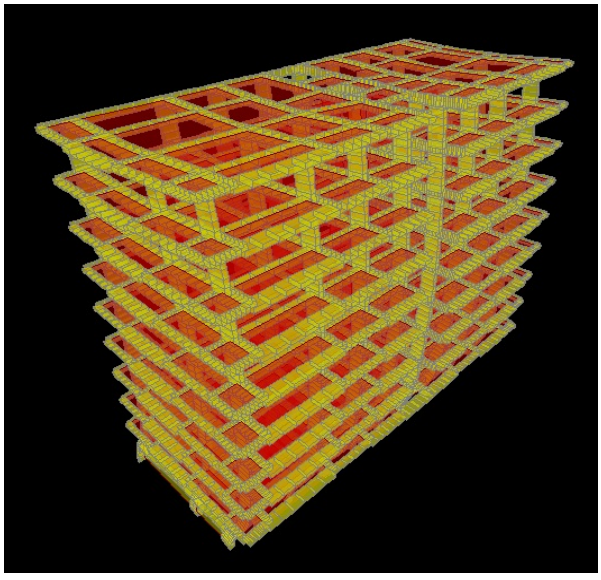

Fig 9. 2. Mode shape (*T*= 0.838 s)

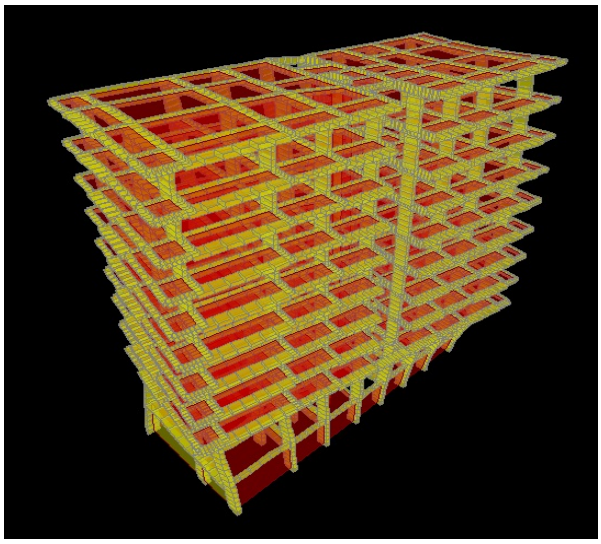

Fig 10. 3. Mode shape (*T*= 0.677 s)

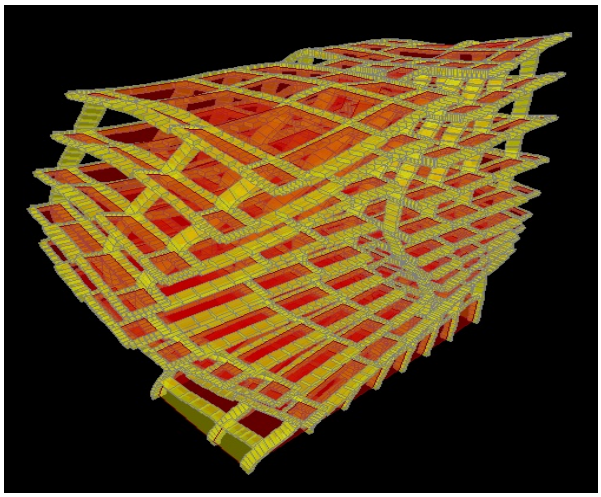

Fig 11. 4. Mode shape (*T*= 0.213 s)

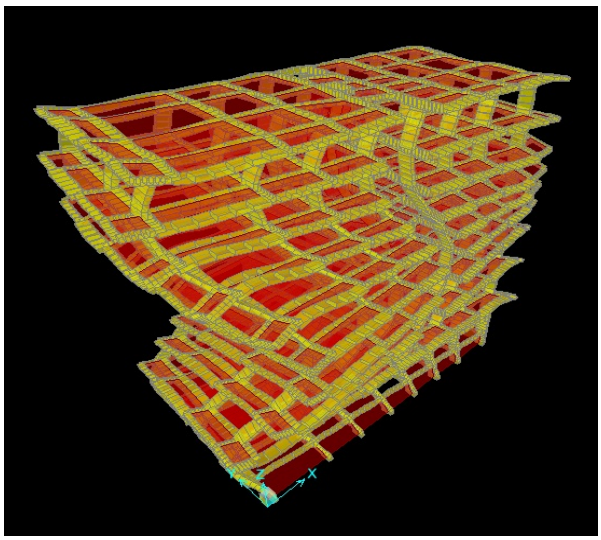

Fig 12. 5. Mode shape (*T*= 0.196 s)

The comparison of period of the model with CFRP and without CFRP model is given in Table 3.

Table 3. Comparison Period of RC building and with CFRP RC Building

Mode	1	2	3	4	5
Non- CFRP	1.072	1.005	0.771	0.314	0.288
Reinforced CFRP	0.940	0.838	0.677	0.213	0.196
Difference (sec)	-0.132	-0.167	-0.094	-0.101	-0.092
Difference (%)	12.31	16.62	12.19	32.17	31.94

Non- CFRP: Period of existing RC building

Reinforced CFRP: Period of RC building reinforced with CFRP

When the mode shapes are examined, the modal shapes are similar in both cases. A huge difference between them was not observed. However, when analyzed as animation, it was seen that large displacements were replaced by torsions.

V. CONCLUSIONS

In this study, as a result of the reinforcement made by wrapping 1 mm thick CFRP fabric into slabsRC building, the percentage changes in the parameters of the structure are listed below.

In the mode 1, the period difference between non-CFRP and CFRP status was obtained as -0.132 sec. The effect of CFRP reinforcing as a percentage was determined as 12.31%.

In the mode 2, the period difference between CFRP and non-CFRP status was obtained as -0.167sec. The effect of CFRP reinforcing as a percentage was determined as 16.62%.

In the mode 3, the period difference between CFRP and non-CFRP status was obtained as -0.094 sec. The effect of CFRP reinforcing as a percentage was determined as 12.19%.

In the mode 4, the period difference between CFRP and non-CFRP status was obtained as -0.101 sec. The effect of CFRP reinforcing as a percentage was determined as 32.17%.

In the mode 5, the period difference between CFRP and non-CFRP status was obtained as -0,092 sec. The effect of CFRP reinforcing as a percentage was determined as 31.94%.

With the reinforcement of the RC building with CFRP, a decrease in the periods is clearly visible. Especially when the dominant period is analyzed, a 12,31 percent decrease is observed. It is also known that the reduction in periods removes the structure from the resonance range and increases the stiffness.

When the analysis results are examined, it is clearly seen in this study that reinforcing the RC building with CFRP makes the RC buildings safer.

In the light of all these findings, CFRP reinforcement method can be used in RC buildings.

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