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INVESTIGATION OF TUNNEL FORMWORK STRUCTURE RETROFITTED WITH JFRP BY FINITE ELEMENT METHOD

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ABSTRACT

In reinforced concrete structures, some repair and strengthening needs may arise before the service life expires. The most common of these strengthening methods are sheathing, reinforcement with steel flats or steel plates. In addition to these, reinforcements made with fiber-reinforced polymers (FRP) have recently gained great momentum in the world. Reinforcements made with FRP materials provide advantages in terms of application speed and ease. In addition, FRP materials do not cause large volumetric increases in the reinforced concrete element to which it is applied. They are usually applied as a thin layer. Therefore, they do not cause loss of space architecturally. These materials are highly resistant to external influences. Many studies have shown that FRP materials can work in harmony with reinforced concrete structures.

In this study, a 5-storey building consisting of reinforced concrete shear wall and slab was modeled in the SAP2000 program. First, the existing structure was analyzed. Then, 2 mm thick JFRP (Jute Fiber Reinforced Polymer) was applied to one side of shear walls and analysis was made. The aim of this study is to examine the effect of the JFRP material applied to the reinforced concrete shear walls on the period and displacement values of the structure.

As a result of the analyzes and comparisons made, it was seen that the dominant period of the JFRP applied structure decreased by 12.03% compared to the existing structure. The maximum displacement in the structure is reduced by 1.10% compared to the existing structure. The study showed that the JFRP material applied to reinforced concrete shear walls provides a significant improvement in the period value of the structure.

Keywords: JFRP; modal parameters; tunnel formwork; FEM.

I. INTRODUCTION

Buildings are exposed to various destructive effects over time due to earthquakes or many different external factors. When an earthquake occurs, seismic forces cause various strains on the structure. These strains can cause damage to the carrier structural element. Especially considering the performance of the building, reducing the effect of seismic loads on the building is very important in terms of reinforcement. Strengthening without increasing the building mass affects the earthquake performance very positively. For this reason, reinforcements with FRP composites have become very common recently. [1], [2], [3], [4].

Fiber reinforced polymers called FRP (Fiber Reinforced Polymer). It is obtained by combining high-strength fibers with a resin matrix, which has a binding feature and a plastic raw material, and other additives. These materials are widely used reinforcement materials around the world. Compared to the steel plate-plate material that is generally used in reinforcement, the greatest advantage of FRP materials is their corrosion resistance. Compared to metals, they are more resistant to many external effects. They are light and thin materials. These materials, whose application methods are easy and practical, are very long-lasting. In FRP materials, material strength can be adjusted by playing with the alignment directions of the fibers in the desired direction. Compared to other strengthening methods, it has the ability to enter places where concrete or steel cannot. [5], [6].

FRP composites are produced by utilizing various superior properties of fibers. Basalt, Carbon, Glass and Jute are examples of these fibers. These composites can be produced in different forms such as reinforcement, strip, fabric and plate. The composite form to be used is selected depending on the type of reinforcement to be made. Many experimental studies have been conducted on FRP composites. These studies have revealed many parameters depending on the winding shape of the FRP strip and the number of turns of the efficiency to be obtained from the reinforcement. [7], [8], [9], [10], [11], [12], [13]. There are many theoretical and experimental studies on JFRP. These studies have shown that concrete elements reinforced using JFRP increase the maximum load capacity. [14], [15], [16].

The aim of this study is to investigate the effects of the reinforcement of reinforced concrete structures manufactured with tunnel formwork with Jute Fiber Reinforced Polymer (JFRP) on the modal parameters of the structure. For this purpose, a reinforced concrete structure manufactured with a sample tunnel formwork will be created using the finite element method. The created model will be strengthened using Jute Fiber Reinforced Polymer (JFRP). As a result of the analyzes, the results obtained by using the literature studies will be examined and the effects on the modal parameters will be evaluated.

II. MATERIAL AND METHOD

A. Description of Jute Fiber Reinforced Polymer (JFRP)

In addition to their ecological benefits, the usage areas of natural fiber reinforced composite materials are increasing day by day due to their high mechanical properties with their low weight. One of the most common of these is fibers made from plants. Fiber plant species affect many physical, mechanical and chemical properties of the composite material to be formed. In addition, the fiber to be used plays a major role in determining the economy of the composite to be produced. In addition, the ability of the materials to work in harmony with each other is an important criterion in the selection of these materials to be used in the industry.

In recent years, increasing requirements for the development of sustainable materials have increased the use of fibers such as flax, hemp, abaca, jute, ramie, sisal and kenaf in natural composites. Jute fibers are from the Corchorus family and there are about 100 types. It is one of the cheapest plants of natural fibers. In addition, it has the highest production volume. It is widely cultivated in China, India and Bangladesh. In addition to their economic and ecological benefits, JFRP composites attract the attention of academia and industry due to their low weight, due to their low density, high specific strength, high fracture strength, toughness, hardness, corrosion resistance. JFRP composites; They are produced using methods such as hand laying, spraying, resin transfer, pressure molding, vacuum molding. [17], [18], [19], [20], [21], [22], [23].

In this study, 2 mm thick JFRP fabric will be used. The picture of the JFRP material to be used is given in figure 1.

Fig. 1. JFRP Fabric

The mechanical properties of JFRP are included in SAP2000 as follows.

Mass and Weight of Material:

1- Weight per Unit Volume = 1400.00 kgf/m^3

2- Mass per Unit Volume = 140.00 kgf/m^3

Mechanical Properties of Material:

1- Modulus of Elasticity:

E1 = 5000.00 kgf/mm^2

E2 = 5000.00 kgf/mm^2

E3 = 5000.00 kgf/mm^2

2- Poisson's Ratio:

U12 = 0.26

U13 = 0.26

U23 = 0.26

B. Description of Concrete Structure

The structure consists of reinforced concrete shear walls and slabs. Shear wall's and slab's thicknesses are 15 cm. The type of concrete used is C25 (in Turkish Standarts). The type of rebar used is S420 (in Turkish Standarts). The length of the building in the x-axis direction is 9 m, and its length in the y-axis direction is 9 m. The building has five floors and its total height is 15 m.

The properties of the reinforced concrete structure and JFRP material were entered into the SAP2000 program. In this study, one-sided 2 mm thick JFRP will be applied to the shear walls of the building. The analysis results obtained will be compared with the analysis results of the existing structure.

TABLE I. THE THICKNESS OF CONCRETE SHEAR WALL AND JFRP LAYER

Material Name	Thickness (mm)
Concrete Shear Wall	150
JFRP	2

The mechanical properties of concrete materials were introduced into SAP2000 software as follows.
Mass and Weight of Material:
1- Weight per Unit Volume = 2499.26 kgf/m^3
2- Mass per Unit Volume = 254.85 kgf/m^3
Mechanical Properties of Material:
1- Modulus of Elasticity:
E1 = 3025.00 kgf/mm^2
2-Poisson's Ratio:
U12 = 0.2

III. RESULTS AND DISCUSSION

The analysis for existing and after structure retrofitted with JFRP was performed using the finite element method, respectively. The studies were examined under separate headings and the resulting data were presented, mode forms and period values for mode are given and compared separately in both cases.

A. Analysis of Existing Structure

The 3D model of the building was created in the SAP2000 program. The created model is presented in figure 2.

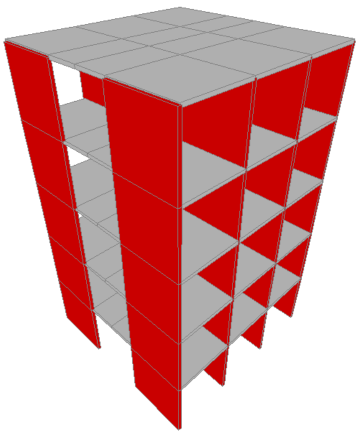
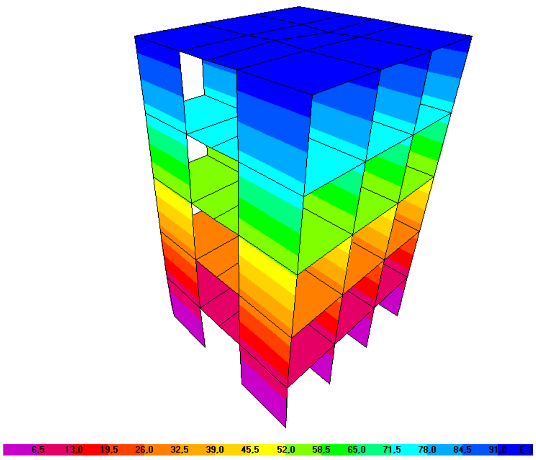


Fig. 2. 3D View of Existing Structure

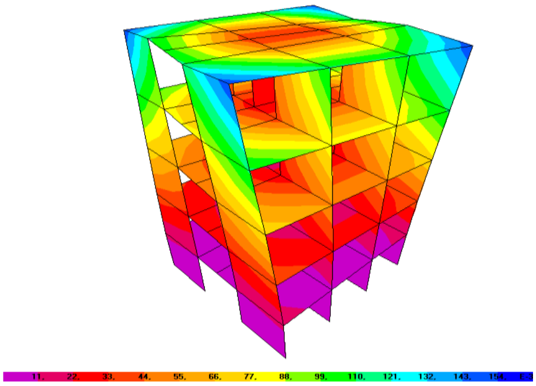
The results of the typical analysis before applying JFRP to the concrete shear walls are shown in table 2 and the mode shapes and displacements respectively given in figure 3 and figure 4.

TABLE II. PERIOD VALUES OF EXISTING STRUCTURE

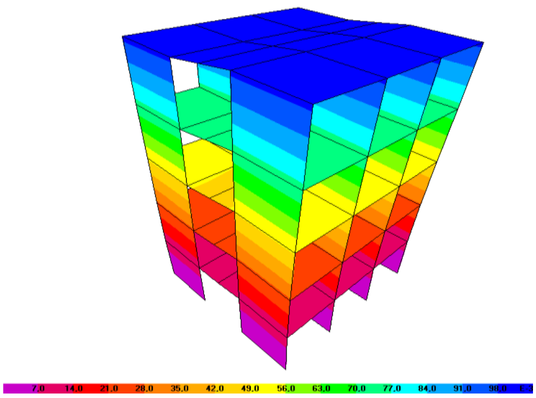
Mode No	Period (s)
1	0.3525
2	0.2338
3	0.1795
4	0.0909
5	0.0495



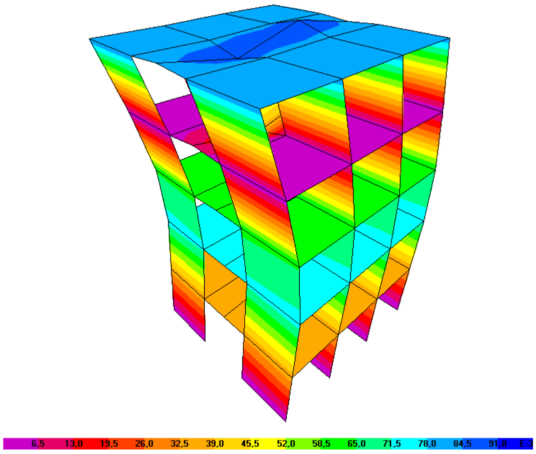
Mode-1



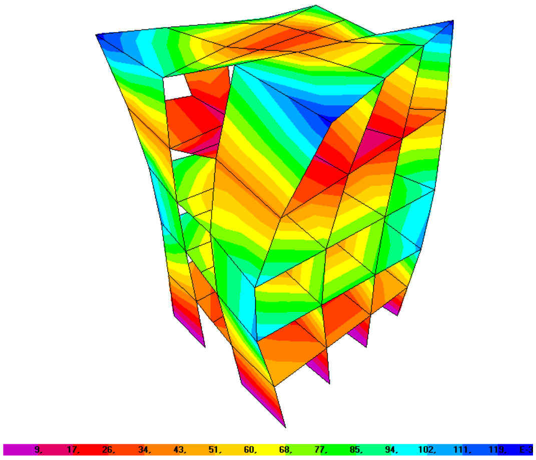
Mode-2



Mode-3



Mode-4



Mode-5

Fig. 3. Mode Shapes of Existing Structure (Mode 1-5)

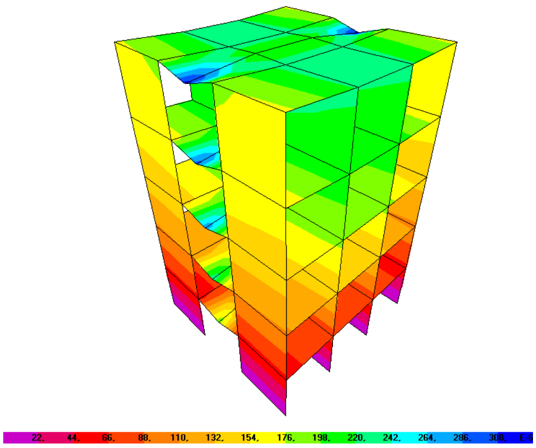


Fig. 4. Displacements of Existing Structure

B. Analysis of Structure Retrofitted with JFRP

The reinforced concrete structure model designed with the finite element method and applied JFRP is shown in figure 5. In this study, JFRP fabric technique was used as a reinforcement method. 2 mm thick JFRP was applied to the walls of the building unilaterally. Analysis results were produced by the SAP2000 program.

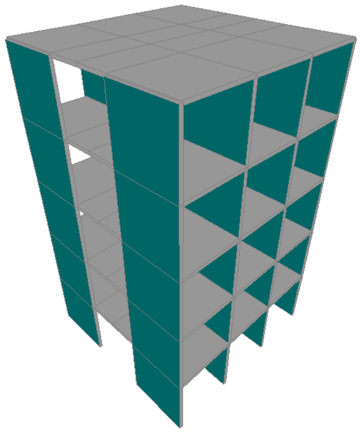
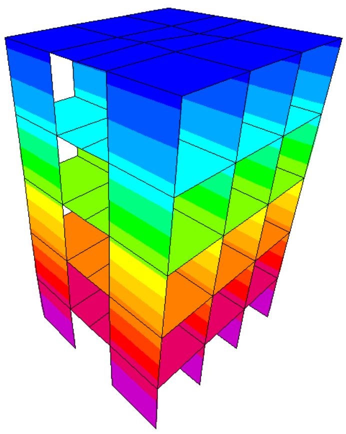


Fig. 5. 3D View of Structure Retrofitted with JFRP

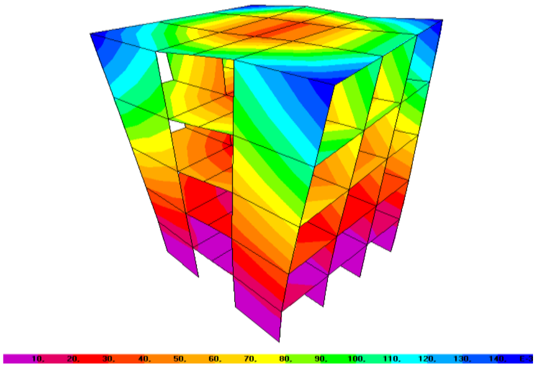
The results of the typical analysis after applying JFRP to the concrete shear walls are shown in table 3 and the mode shapes and displacements respectively given in figure 6 and figure 7.

TABLE III. PERIOD VALUES OF STRUCTURE RETROFITTED WITH JFRP

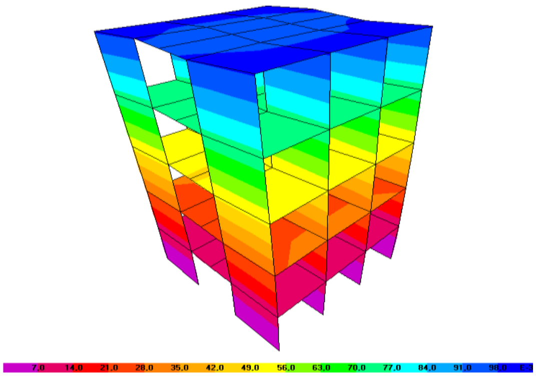
Mode No	Period (s)
1	0.3101
2	0.2196
3	0.1621
4	0.0820
5	0.0479



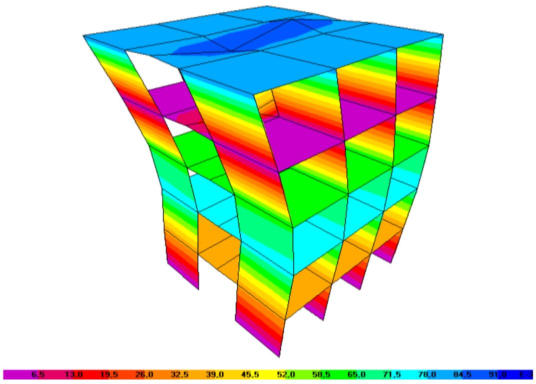
Mode-1



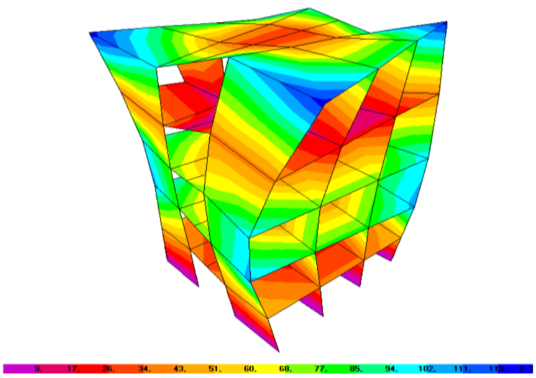
Mode-2



Mode-3



Mode-4



Mode-5

Fig. 6. Mode Shapes of Structure Retrofitted with JFRP (Mode 1-5)

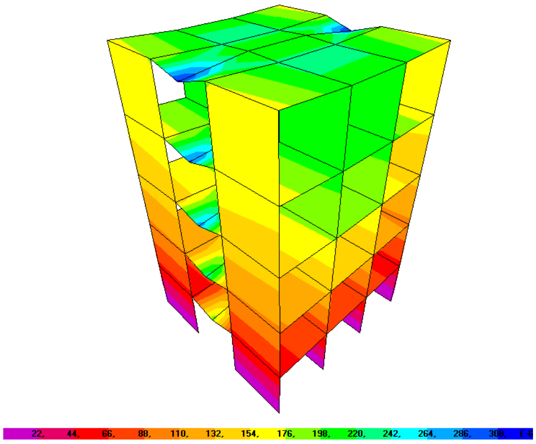


Fig. 7. Displacements of Structure Retrofitted with JFRP

C. Comprasion of Analysis Results

The comparison of period of existing structure and retrofitted with JFRP is given in table 4.

TABLE IV. PERIOD'S COMPRASION BEFORE AND AFTER APPLYING JFRP

Mode No	Diffrence (s)	Difference (%)
1-1	-0.0424	12.03
2-2	-0.0142	6.07
3-3	-0.0174	9.69
4-4	-0.0089	9.79
5-5	0.0016	3.23

IV. CONCLUSIONS

In this study, 2 mm JFRP was applied unilaterally to the 15 cm thick shear walls of the building. According to the results of the SAP2000 program as a result of the strengthening, the proportional changes in the parameters of the structure are listed below.

- In the mode 1, the period difference between existing structure and retrofitted with JFRP observed as -0.0424 s. The effect of JFRP reinforcement was determined to be a 12.03% reduction in period.
- In the mode 2, the period difference between existing structure and retrofitted with JFRP observed as -0.0142 s. The effect of JFRP reinforcement was determined to be a 6.07% reduction in period.
- In the mode 3, the period difference between existing structure and retrofitted with JFRP observed as -0.0174 s. The effect of JFRP reinforcement was determined to be a 9.69% reduction in period.
- In the mode 4, the period difference between existing structure and retrofitted with JFRP observed as -0.0089 s. The effect of JFRP reinforcement was determined to be a 9.79% reduction in period.
- In the mode 5, the period difference between existing structure and retrofitted with JFRP observed as -0.0016 s. The effect of JFRP reinforcement was determined to be a 3.23% reduction in period.
- Maximum displacements difference between existing structure and retrofitted with JFRP observed as -0.00035 cm. The effect of JFRP reinforcement was determined to be a 1.10% reduction in displacement.

It is seen that there is a decrease in the periods with the reinforcement of the walls of the building retrofitted with JFRP. When the peak period of the structure is examined, it is seen that there is a decrease of 12.03%. In this study, it is seen that JFRP applied to reinforced concrete walls increases the rigidity of the structure and makes the structure safer. In the light of all these findings, JFRP reinforcement method can be used in reinforced concrete buildings consisting of shear wall systems (tunnel formwork).

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