THE EFFECT OF GFRP REINFORCED SQUARE CONCRETE CHIMNEY ON MODAL PARAMETERS USING FINITE ELEMENT METHOD

Furkan Günday
Ondokuz Mayis University, Faculty of Engineering, Department of Civil Engineering, Samsun, Turkey
* furkan.gunday@omu.edu.tr
Anas M.S Alihassan
Ondokuz Mayis University, Faculty of Engineering, Department of Civil Engineering, Samsun, Turkey

Abstract
There is a growing concern with worldwide deterioration of traditional materials such as concrete, steel, and timber. Recently, attention has shifted to the use of fiber reinforced polymer composites (FRPs) as alternative materials. As FRPs are non-corrosive, high strength and modulus values compared to their density, light weight, acceptable deformability, tailored design and excellent formability enable the fabrication of new elements and the structural rehabilitation of the existing parts made of traditional materials. Furthermore, the resistance of FRP materials to corrosion means that they can be used to replace steel and reinforced concrete in situations when they would be exposed to corrosion. FRP therefore has wide application prospects in civil engineering ranging from reinforcing rods and tendons, wraps for seismic retrofit of columns and externally bonded reinforcement for strengthening of walls, beams, and slabs, to all-composite bridge decks, and even hybrid and all-composite structural systems. The method of strengthening with GFRP has been used in many studies recently. Therefore, this study was conducted. In this study, as a result of the reinforcement made by wrapping 2 mm thick GFRP fabric into the 20 m height concrete chimney structure. The differences between modal parameters of the concrete chimney and GFRP reinforced concrete chimney were compared. These modal parameters are period and mode shapes. The first 5 modes of the situation with and without GFRP were examined with finite element method. A difference of 0.8% - 1.5% was observed in the periods of the first 5 modes. Reinforcement with GFRP has been observed to be positive for safety on the concrete chimneys.

Keywords: GFRP, Square Concrete Chimney, FEM, Modal Parameters

Introduction
Industrial chimneys are vertical structures that allow hot toxic gases to be released into the atmosphere. It is not always possible to withstand the chimney dead loads, wind loads, effects of temperature change and seismic loads. Therefore, they need to be reinforced from time to time. Glass fiber reinforced plastic (GFRP) materials are preferred in the reinforcement of industrial chimneys due to their high corrosion and chemical resistance. Strengthening the structural members of old buildings using advanced materials is a contemporary research in the field of repairs and rehabilitation. Many studies [2], [3], [4], [5], [8], [9], [13] used Glass Fiber Reinforced Polymer (GFRP) for strengthening Reinforced Concrete (RC) chimneys. Industrial reinforced concrete chimneys were reinforced with GFRP layer and their dynamic analysis was performed with finite element method. Dynamic parameters were compared between the GFRP amplified state and the state before reinforcement. The differences were revealed by examining all the effective parameters (frequency, mode shape, etc) in the dynamic behaviour before and after the reinforcement.
Surface preparation is very important for GFRP materials. Surface preparation is very important for GFRP 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 GFRP in structures is the stripping of the material or separating the concrete by taking the cover layer.
The studies have been examined under separate titles and the data obtained have been presented. In both cases, the mode shapes and the period values of the mode are given separately and compared. Thus, it is aimed to reveal the effect of GFRP reinforced on the modal parameters of square concrete chimneys.

Material and Method

Description of Glass Fiber Reinforced Polymer

Among reinforcements, Fiberglass Fabrics continue to be the most commonly used reinforcement in the composites industry today. Generally, they are the least expensive among reinforcements and offer ease in handling. And when combined with resin, deliver composite parts with excellent strength, low weight, and great cosmetics. All Fiberglass Fabrics are woven for fiber orientation, and each fabric features its own unique weight, strength, and fabric characteristics, which should be considered before starting any project. Fiberglass is a strong lightweight composite material and is used for many products. Although it is neither as strong nor stiff when compared to carbon fiber, it is less brittle and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily molded into complex shapes. Applications of fiberglass include aircraft, boats and automobiles. We carry glass fiber fabrics, prepregs, and spools. We can provide a high volume of product to industry or the small volumes needed for prototypes.
With GFRP fabrics (figure 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 GFRP fabric and structure that will affect the adherence of any dust particles should be careful [6], [7], [12].

Figure 1: GFRP Fabric

The most important advantage of GFRP fabrics is that it gives a much more rigidity than conventional methods with a few millimetres of material reinforced to the structure [6], [7].
The material to be used for the planned reinforcement is given in figure 1. The thickness of the GFRP fabric to be used is designed as 2 mm. The parameters of the material are given separately under "Mechanical Properties of GFRP Material"

Mechanical Properties of GFRP Material

In this study, SAP 2000, a package program that uses finite element method, is used. The mechanical properties of the GFRP material were entered into the SAP 2000 program as follows;

Mass and Weight of Material:
1- Unit Volume Weight = 1900.65 kgf / m^3,
2- Unit Volume Mass = 1900.65 kgf / m^3.
Mechanical Properties of Material:
1- Elasticity Module:
E1 = 4078.86 kgf/mm^2,
E2 = 4078.86 kgf/mm^2,
E3 = 815.77 kgf/mm^2.
2- Poison Rate:
U12 = 0.25,
U13 = 0.25,
U23 = 0.25.

Description of Concrete Chimney

First, the features of the concrete chimney and the properties of the GFRP material were entered into the SAP 2000 program. In this study, GFRP material will be applied to the entire surface. Thus, all cracks on surface will be closed. The area of square concrete chimney is 50*50 cm, while the height of concrete's chimney is 20m, the concrete used in the concrete chimney is C20/25. Concrete thickness of the concrete chimney is 0.015 m.
In this study, the analysis was made using the finite element method for the current state and the state after reinforcement, respectively. The studies have been examined under separate titles and the data obtained have been presented. In both cases, the mode shapes and the period values of the mode are given separately and compared.
The concrete chimney wall thickness and GFRP thicknesses to be used are given in Table 1.

Table 1. Thickness of Concrete Chimney and GFRP Layers

Material Name	**Thickness (mm)**
Concrete Chimney	150
GFRP	2

Results and Discussion

In this section, the analysis was made using the finite element method for the current state and the state after reinforcement, respectively. The studies have been examined under separate titles and the data obtained have been presented. In both cases, the mode shapes and the period values of the mode are given separately and compared.

Analysis of Concrete Chimney Without GFRP

The 3D finite element model of the Square concrete chimney was created with the SAP 2000 program. Square concrete chimney finite element model without GFRP is given in figure 2.

Figure 2: Concrete Chimney Finite Element Model without GFRP

Modal analysis results before applying GFRP to the concrete chimney are given in Table 2 and respectively mode shapes given figure 3.

Table 2. Period of Concrete Chimney without GFRP

Mode Number	**Period (s)**
1	0.77400
2	0.12464
3	0.04093
4	0.01609
5	0.01244

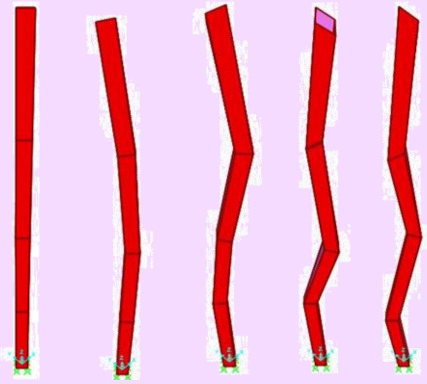

Figure 3: Respectively Mode Shapes of Concrete Chimney without GFRP

Analysis of Concrete Chimney With GFRP

The finite element model of the concrete chimney given in Figure 4 is the reinforced situation. In other words, it is GFRP reinforced. GFRP fabric technique is used in this study as this reinforcement method. GFRP fabric thickness is 2 mm. GFRP fabric is applied to the entire outer surface. SAP2000 package program was used to obtain the analysis data.

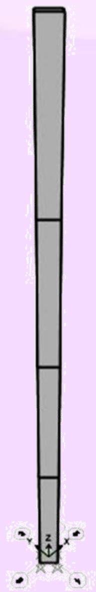

Figure 4: Concrete Chimney Finite Element Model with GFRP

Modal analysis results after applying GFRP to the concrete chimney are given in Table 3 and mode shapes given figure 5.

Table 3. Period of Concrete Chimney with GFRP

Mode Number	**Period (s)**
1	0.76722
2	0.12355
3	0.04058
4	0.01599
5	0.01226

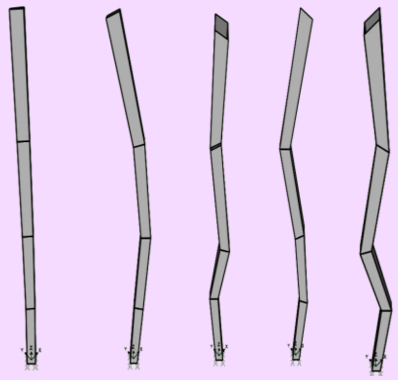

Figure 5: Respectively Mode Shapes of Concrete Chimney with GFRP

Comparison of Analysis Results

The comparison of period of the model without GFRP and with GFRP model is given in Table 4.

Table 4. Comparison Period of without GFRP Model and with GFRP Model

Mode Number	Difference (s)	Difference (%)
1-1	-0.00678	0.88
2-2	-0.00109	0.87
3-3	-0.00035	0.84
4-4	-0.0001	0.63
5-5	-0.00018	1.44

Table 4 illustrates the effect of GFRP on the period.

When the mode shapes are examined, the modal shapes are slight differences. A huge difference between them was not observed. However, when analysed as animation, it was seen that large displacements were replaced by torsions. Changes in the third, fourth and fifth mode shapes are noticeable. With GFRP, mode shapes with more balanced displacements in 3 directions are seen instead of large displacements in one direction.

Conclusions

In this study, as a result of the reinforcement made by wrapping 2 mm thick GFRP fabric into the 150 mm thick concrete chimney structure, the percentage changes in the parameters of the structure are listed below.

In the mode 1, the period difference between non-GFRP and GFRP status was obtained as -0.00678s. The effect of GFRP reinforcing as a percentage was determined as 0.88%.

In the mode 2, the period difference between GFRP and non-GFRP status was obtained as -0.00109 s. The effect of GFRP reinforcing as a percentage was determined as 0.87%.

In the mode 3, the period difference between GFRP and non-GFRP status was obtained as -0,00035 s. The effect of GFRP reinforcing as a percentage was determined as 0.84%.

In the mode 4, the period difference between GFRP and non-GFRP status was obtained as -0,0001 s. The effect of GFRP reinforcing as a percentage was determined as 0.63%.

In the mode 5, the period difference between GFRP and non-GFRP status was obtained as -0,00018 s. The effect of GFRP reinforcing as a percentage was determined as 1.44%.

With the reinforcement of the concrete chimney with GFRP, a decrease in the periods is clearly visible. Especially when the dominant period is analyzed, a 0.88 percent decrease is observed. It is also known that the reduction in periods removes the structure from the resonance range and increases the stiffness.

With GFRP, modal shapes with more balanced displacements in 3 directions are seen instead of large displacements in one direction.

It is predicted that the effect of strengthening with GFRP will increase even more by increasing the thickness of GFRP. In this study, based on only the simplest application, 2 mm thickness, in other words, single layer application is taken as basis. Thus, the most fundamental effects have been revealed.

In the light of all these findings, GFRP reinforcement method can be used in square concrete chimneys.

References

1. Kasimzade, A.A., & Tuhta S. (2012). Analytical, numerical and experimental examination of reinforced composites beams covered with carbon fiber reinforced plastic, Journal of Theoretical and Applied Mechanics, vol. 42, pp. 55- 70.
2. Kasimzade, A.A., & Tuhta, S. (2017) OMA of model steel structure retrofitted with GFRP using earthquake simulator, Earthquakes and Structures, vol. 12, pp. 689-697.
3. Kasimzade, A.A., & Tuhta, S. (2005) Finite Element, Analytical, Experimental Investigation of Reinforced Concrete Beams Strengthened with GFRP and Related Structure Analysis Problem's Solutions, AACEU, Scientific Works No 2, pp.18-26.
4. Bastianini, F., M. Corradi, A. Borri, & Angelo di Tommaso A. (2005). Retrofit and monitoring of an historical building using "Smart" GFRP with embedded fibre optic, Construction and Building Materials.
5. La Mendola, L., M. Accardi, C. Cucchiara, & V. Licata. (2014). Nonlinear FE analysis of out-of plane behaviour of masonry walls with and without GFRP reinforcement, Construction Building Material.
6. Tuhta, S., Günday, F., Aydin, H., & Pehlivan, N. Ç. (2019). Investigation of GFRP Retrofitting Effect on Masonry Dome on Period and Frequency Using Finite Element Method. Presented at the International Disaster and Resilience Congress (idRc 2019), Eskişehir.
7. Tuhta, S., Günday, F., Aydin, H., & Pehlivan, N. Ç. (2019). Investigation of GFRP Retrofitting Effect on Masonry Dome on Stress Using Finite Element Method. Presented at the International Disaster and Resilience Congress (idRc 2019), Eskişehir.
8. Ziada, M., Tuhta, S., Gençbay, E. H., Günday, F., & Tammam, Y. (2019). Analysis of Tunnel Form Building Retrofitted with CFRP using Finite Element Method. International Journal of Trend in Scientific Research and Development, 3(2), 822–826.
9. Günday, F. (2018). GFRP Retrofitting Effect on the Dynamic Characteristics of Model Steel Structure Using SSI. International Journal of Advance Engineering and Research Development, 5(4), 1160-1173.
10. Günday, F. (2018). OMA of RC Industrial Building Retrofitted with CFRP using SSI. International Journal of Advance Engineering and Research Development, 5(5), 759-771.Tuhta, S., Abrar, O., & Günday, F. (2019). Experimental Study on Behavior of Bench-Scale Steel Structure Retrofitted with CFRP Composites under Ambient Vibration. European Journal of Engineering Research and Science, 4(5), 109–114.
11. Tuhta, S., Günday, F., & Pehlivan, N. C. (2019). Investigation of Cfrp Retrofitting Effect on Masonry Dome on Bending Moment Using Finite Element Method. International Journal of Innovatıons in Engineering Research and Technology, 6(6), 18–22.
12. Tuhta, S., Günday, F., & Aydin, H. (2019). Dynamic Analysis of Model Steel Structures Retrofitted with GFRP Composites under Microtremor Vibration. International Journal of Trend in Scientific Research and Development, 3(2), 729–733.
13. Tuhta, S., Günday, F., & Alihassan, A. (2020). The Effect of CFRP Reinforced Concrete Chimney on Modal Parameters Using Finite Element Method. International Journal of Innovations in Engineering Research and Technology, 7(2), 1–6.
14. Tuhta, S., Günday, F., & Alihassan, A. (2020). System Identification of Model Steel Chimney with Fuzzy Logic. International Journal of Research and Innovation in Applied Science, 5(1), 11–15.