INVESTIGATION OF CFRP RETROFITTING EFFECT ON MASONRY DOME ON BENDING MOMENT USING FINITE ELEMENT METHOD

SERTAÇ TUHTA
Department of Civil Engineering , Ondokuz Mayıs University / Samsun, Turkey
* stuhta@omu.edu.tr

FURKAN GÜNDAY
Department of Civil Engineering , Ondokuz Mayıs University / Samsun, Turkey
* furkangunday@omu.edu.tr

NERIMAN ÇAĞLA PEHLİVAN
Department of Civil Engineering , Ondokuz Mayıs University / Samsun, Turkey

ABSTRACT
A variety of methods are used in the repair and strengthening of masonry structures. Some of them use traditional materials, but in cases where they are insufficient, new materials are used. Some interventions may take the form of repairs to several elements, while others strengthen the structure as a whole. In addition, it is always desirable that the bending moment in the structures are low. It is extremely important to observe this effect. Therefore, this study was conducted. In this study, as a result of the reinforcement made by wrapping 1 mm thick CFRP fabric into the 100 mm thick masonry dome structure. The differences between maximum bending moment of the masonry domes and CFRP reinforced masonry domes were compared.
While these differences were observed to be 37.26% in a percentage. This difference was observed when there was a positive decrease. Reinforcement with CFRP has been observed to be positive for safety on the masonry dome.

KEYWORDS: CFRP, Masonry Dome, Bending Moment, Retrofitting, FEM

INTRODUCTION
Masonry structures are an important part of cultural heritage and contain the sociological, economic, cultural and political elements of the place and the past and offer us the opportunity to research the past. It is not wrong to say that masonry domes, which are a carrier type of masonry structures, are usually within the historical monument. Therefore, strengthening of these systems should also be done within the framework of important and specific rules. Earthquakes, natural disasters and adverse environmental conditions damage these structures. Finding a better strengthening method in the strengthening of masonry domes in today's conditions is essential for transferring these structures to future periods. The aim of this study is to give general information about the types of reinforcement applied in domes and masonry structures and to analyze the contribution of the structure to the stability of the structure by analyzing the dome sample, which is being used in strengthening masonry structures thanks to today's technology.

DESCRIPTION OF CARBON FIBER REINFORCED POLYMER
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 the tensile strength of masonry buildings is low, it is evident that the ductility of the building will increase and affect their behavior against earthquake loads positively.

Figure 1. CFRP Fabric

With CFRP fabrics (fig 1), the outer surfaces of masonry walls, 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.

The most important advantage of CFRP fabrics is that it gives a much more rigidity than conventional methods with a few millimeters of material reinforced to the structure.

MECHANICAL PROPERTIES OF CFRP MATERIAL

The mechanical properties of the CFRP material were entered into the SAP 2000 program as follows. Mass and Weight of Material: 1- Unit Volume Weight = 1600,55 kgf / m^3, 2- Unit Volume Mass = 163.15 kgf / m^3. Mechanical Properties of Material: 1- Elasticity Module: E1 = 13766,17 kgf/mm^2, E2 = 13766,17 kgf/mm^2, E3 = 1019,7 kgf/mm^2. 2- Poison Rate: U12 = 0,3, U13 = 0,3, U23 = 0,022.

DESCRIPTION OF MASONRY DOME

First, the features of the masonry dome and the properties of the CFRP material were entered into the SAP 2000 program. In this study, CFRP material will be applied to the entire surface of the dome. Thus, all cracks on the dome will be closed. The masonry dome characteristics were entered in the dimensions indicated in the figures 2-3-4.

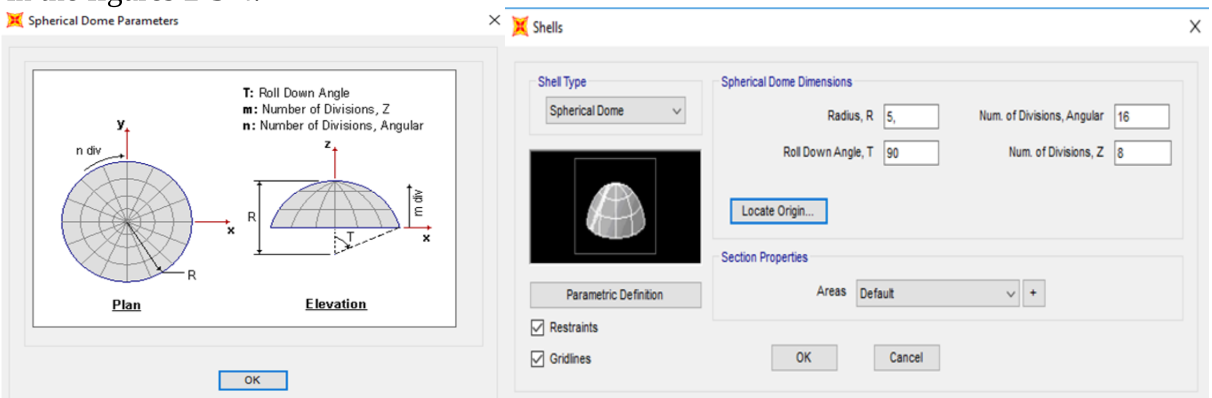

Figure 2. Physical Parameters of Masonry Dome

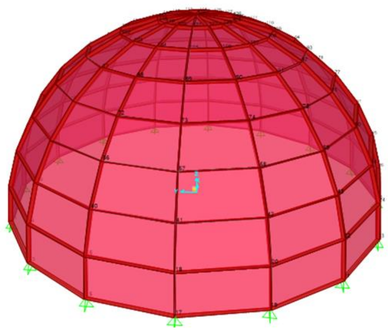

Figure 3. 3D View ofMasonry Dome

The stone wall and CFRP thicknesses to be used are given in Table 1.

Table 1. Thickness of Stone Wall and CFRP Layers

Material Name	Thickness (mm)
Stone wall	100
CFRP	1

ANALYSIS OF MASONRY DOME USING FEM

In this part, the above building is analyzed in two different cases: In the 1st case, the building without CFRP is investigated for its responses (Maximum moment). In the 2nd case, the same building is analyzed when CFRP is used to strengthen. Then responses from both cases are compared.

ANALYSIS OF MASONRY DOME WITHOUT CFRP

Max bending moment before applying CFRP to the masonry dome in the SAP 2000 program environment are given in Table 2 and figure 4.

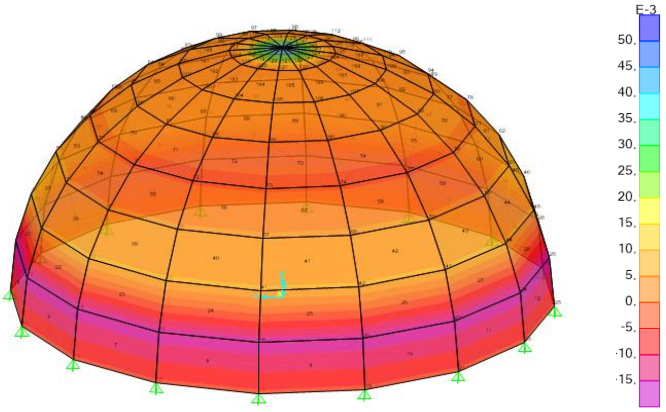

Figure 4. Max Moment of Masonry Dome Without CFRP

Table 2. Max Moment without CFRP

MOMENT	WİTHOUT CFRP (kN)
MMAX	1616,16
MMİN	-1616,16

ANALYSIS OF MASONRY DOME WITH CFRP

Max bending moment after applying CFRP to the masonry dome in the SAP 2000 program environment are given in Table 3 and figure 5.

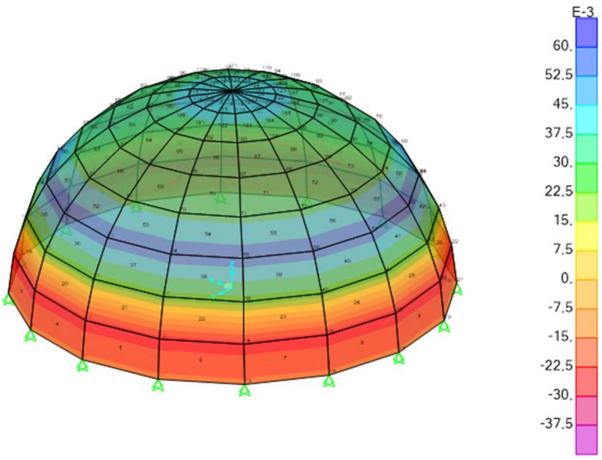

Figure 5. Max Moment of Masonry Dome With CFRP

Table 3. Max Moment with CFRP

MOMENT	WİTH CFRP (kN)
MMAX	1014
MMİN	-1014

COMPARISON OF ANALYSIS RESULTS

The comparison of max-min moment of the model with CFRP and without CFRP model is given in Table 4.

Table 4. Comparison Bending Moment of Without CFRP Model and With CFRP Model

MOMENT	WİTHOUT CFRP (kN)	WİTH CFRP (kN)	DİFFERENCE	DİFFERENCE %
MMAX	1616.16	1014	602.16	37.26%
MMİN	-1616.16	-1014	-602.16	37.26%

CONCLUSIONS

In this study, as a result of the reinforcement made by wrapping 0.1 mm thick CFRP fabric into the 10 mm thick masonry dome structure, the percentage changes in the parameters of the structure are listed below.

It was found that maximum moment values decreased by 37.26 percent.

Figure 4 and figure 5, it is seen that the moment values decrease almost everywhere in the masonry dome. In the light of this information, it should not be ignored that the reinforcement of the masonry dome with CFRP has a positive effect on the moment of the masonry dome.

With all these findings, it is seen that the reinforcement of masonry domes with CFRP is very beneficial on the reduction of maximum moment.

It is recommended to use a thin one-way CFRP layer to cover all visible and invisible cracks in the walls of the masonry structure, to make the workmanship of the process easier and to keep the material cost lower.

REFERENCES

1) Yang, Y., Xue, Y., Yu, Y., Liu, R. and Ke, S., “Study of the design and mechanical performance of a GFRP-concrete composite deck”, Steel and Composite Structures, vol. 24, pp. 679-688, 2017.
2) 19. Keykha, A. H., “Numerical investigation on the behavior of SHS steel frames strengthened using CFRP”, Steel and Composite Structures, vol. 24, pp. 561-568, 2017.
3) 20. Smyrou, E., Karantzikis, M. and Bal, İ. E., “FRP versus traditional strengthening on a typical mid-rise Turkish RC building”, Earthquakes and Structures, vol. 9, pp. 1069-1089, 2015.
4) Elwan, S. K. and Omar, M. A., “Experimental behavior of eccentrically loaded RC slender columns strengthened using GFRP wrapping”, Steel and Composite Structures, vol. 17, pp. 271-285, 2014.
5) Lelli, V.D.E., Lei, Z., Frieder, S., “Use of FRP composites in civil engineering structural applications”. Construction and building materials 17(6-7): 389-403, 2003
6) Kasimzade, A.A. and Tuhta S., “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, 2012.
7) Kasimzade, A.A. and Tuhta, S., “OMA of model steel structure retrofitted with CFRP using earthquake simulator”, Earthquakes and Structures, vol. 12, pp. 689-697, 2017.
8) Kasimzade, A.A. and Tuhta, S., “Finite Element, Analytical, Experimental Investigation of Reinforced Concrete Beams Strengthened with CFRP and Related Structure Analysis Problem’s Solutions”, AACEU, Scientific Works No 2, pp.18-26, 2005.
9) Bastianini, F., M. Corradi, A. Borri, and Angelo di Tommaso A. “Retrofit and monitoring of an historical building using ‘‘Smart’’ CFRP with embedded fibre optic', Construction and Building Materials.,2005
10) La Mendola, L., M. Accardi, C. Cucchiara, and V. Licata. “Nonlinear FE analysis of out-of plane behaviour of masonry walls with and without CFRP reinforcement”, Construction Building Material. 2014.

11) Hosny A., and Elarabi A.,"Strengthening of the Prestressed Concrete Slabs Using CFRP", The Composites in Construction International Conference. Italy. September 16-17.2003.pp.355-360. 2003.
12) Muhamed A. M., Abdel-Hady H., Amr A., "Use of FRP in Egypt, Research Overview and Applications", The 2nd International Conference on Rehabilitation and Maintenance in Civil Engineering. Procedia Engineering. Egypt. 2013
13) Robert S., Katarina G., Ivan H. "FRP Composites and Their Using in the Construction of Bridges". World Multidisciplinary Civil Engineering Architecture Urban Planning Symposium 2016, WMCAUS 2016.
14) Nicolae T., Gabriel O., Mihai B., Alexandru S., Ionel G., "The use of Glass Fiber reinforced Polymer Composites as Reinforcement for Tubular Concrete poles". Proceedings of the 11th WSEAS International Conference on Sustainability in Science Engineering. 2014
15) Victoria J. W., "Use of Fiber Reinforced Polymer (GFRP) Reinforcing bars for concrete bridge decks" Thesis for master of Engineering in Civil engineering, University of Canterbury, New Zealand. 2015
16) Taranu N., Oprisan G., Isopescu D., Entuc I., Munteanu V., Banu C, "Fiber reinforced polymer composites as internal and external reinforcements for buildings elements", 2008
17) Alexandre L., Carlos A., Eduardo M. B., "Mechanical Properties of Glass Fiber Reinforced Polymer Members For structural Applications"., Material Research.2015;18(6): 1372-1383. 2015
18) Gattuli,V., Lampis G., Marcari G., And Paolone A.,"Simulations of FRP Reinforcement in Masonry Panels and Application to a Historical Facade", Engineering Structures, 75:604-418. 2014
19) Williams P. S.,"Glass Fiber Reinforced Polymer (GFRP) and Steel Strengthening of Unreinforced Brick Masonry Piers" Master Thesis in Civil engineering, University of Florida. USA. 2004
20) Ziada M., Tuhta S., Tammam Y., "Analysis of Masonry Structures Retrofitted with Glass Fiber reinforced Polymer Using Finite element Method", International Journal of Advance Engineering and Research Development. Vol 5, Issue 04, e-ISSN: 2348-4470, print-ISSN: 2348-6406. April-2018
21) Günday F., "GFRP Retrofitting Effect on the Dynamic Characteristics of Model Steel Structure Using SSI", International Journal of Advance Engineering and Research Development , 2018
22) [22] Günday F., "OMA of RC Industrial Building Retrofitted with CFRP using SSI", International Journal of Advance Engineering and Research Development , 2018
23) Ziada M., Tuhta S., Gençbay E., Günday F., Tammam Y., "Analysis of Tunnel Form Building Retrofitted with CFRP using Finite Element Method", International Journal of Advance Engineering and Research Development, 2019
24) Tuhta S., Abrar O., Günday F., "Experimental Study on Behavior of Bench-Scale Steel Structure Retrofitted with CFRP Composites under Ambient Vibration", International Journal of Advance Engineering and Research Development, 2019
25) Tuhta S., Günday F., Aydın H., "Dynamic Analysis of Model Steel Structures Retrofitted with GFRP Composites under Microtremor Vibration", International Journal of Advance Engineering and Research Development, 2019