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THE EFFECT OF GFRP STEEL SILO ON MODAL PARAMETERS USING FINITE ELEMENT METHOD

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ABSTRACT

This paper presents a novel method of strengthening cylindrical shells by applying a thin layer of fibre-reinforced polymer (FRP) composite, used at the silo body, can effectively eliminate the problem and increase the buckling strength. The strengthened shell is analysed using finite element method (FEM) in this preliminary study. The method of strengthening with GFRP has been used in many studies recently. Therefore, it was decided to conduct this research. In this study, as a result of the reinforcement made by wrapping 2 mm thick GFRP fabric into the 12 m height Steel silo structure. The differences between modal parameters of the steel silo and GFRP reinforced Steel silo 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 2% - 10% was observed in the periods of the first 5 modes. Reinforcement with GFRP has been observed to be positive effects for safety on the steel silo. GFRP reinforcement method can be used for safety in steel silos.

Keywords: GFRP, Steel silo, Modal parameters, FEM, Reinforcing

INTRODUCTION

Due to their unique deformed shape, thin metal cylindrical shell constructions such as silos and tanks are subject to an elastic–plastic instability failure at their walls. High internal pressure and axial compression in the shell structure cause this type of buckling to occur. It is a common situation in a silo where the silo wall is subjected to both normal pressures from the stored granular solid and vertical compressive forces developed from the friction between the stored solid and the silo wall. 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.

Steel silos are commonly used to store granular solids for long or short periods of time. Granular solids include flour, iron ore pellets, coals, cement, crushed rocks, plastic, chemical compounds, sand, and concrete aggregate, among other things. Silos are thin-walled shells in which buckling failure is a major concern that need specific consideration. Since the early twentieth century, scientists have explored the buckling of a thin metal shell [1]. The classical phase of those studies refers to the time period between the 1900s and the 1970s, when simple load situations and modest geometric flaws were utilized, prior to the computer era, when finite element analysis and non-linear equilibrium routes became powerful tools. Fibre reinforced polymer, or FRP, is made up of two main components: fibres and resin, with the fibres providing strength and the resin binding the fibres together. Carbon, aramid, and glass fibres are used. As a result, the strength of FRP might vary based on the type of fibers employed. Glass Fiber Reinforced Polymer (GFRP) for reinforcing Steel Silos has been studied extensively [3], [4], [5], [6], [7], [9], [13]. Steel silos were reinforced with a GFRP layer, and a finite element analysis was used to determine their dynamic behaviour. 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. For GFRP materials, proper surface preparation is critical. The most significant issue in the deployment of GFRP in structures is the removal of the cover layer, which involves stripping the material or separating the concrete. The studies have been examined under separate titles and the data obtained have been presented.

In this study, we aim to make thin silo walls more resistatable and to seal in case of any cracks or splits on the surface of the wall by wrapping a GFRP layer on the inside surface. And by applying this technic we also will gain more stability too by reducing the period. 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 steel silos.

Description of GFRP

Fiberglass fabrics are still the most widely utilized reinforcement in the composites sector today. They are generally the least cost reinforcements and are the easiest to handle. 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 lightweight composite material that is utilized in a wide range of applications. Although it is not as strong or rigid as carbon fiber, it is less brittle and its raw materials are significantly less expensive. It has superior bulk strength and weight than many metals, and it can be melded into more complex designs with ease. Fiberglass is used in planes, boats, and vehicles, among other things. Glass fiber fabrics, prepregs, and spools are all available. We may supply large quantities of product to industry or small quantities for prototypes. To improve their carrying capacity and ductility under existing loads, the outside surfaces of steel silos, stiffeners, roof sheets, and all body sheets are wrapped with GFRP textiles (figure 1) in the proper direction and width. Preparation of the surface prior to application of all dust and free of material to remove any material between the GFRP fabric and the structure that may affect the adherence of any dust particles should be done with caution [6], [7], [9]. The greatest feature of GFRP fabrics is that they provide significantly higher rigidity than older techniques who just use a few millimetres of material to reinforce the structure. [6],[7]. Figure 1 presents the material that will be utilized for the projected reinforcement. The GFRP fabric to be used is designed to be 2 mm thick.

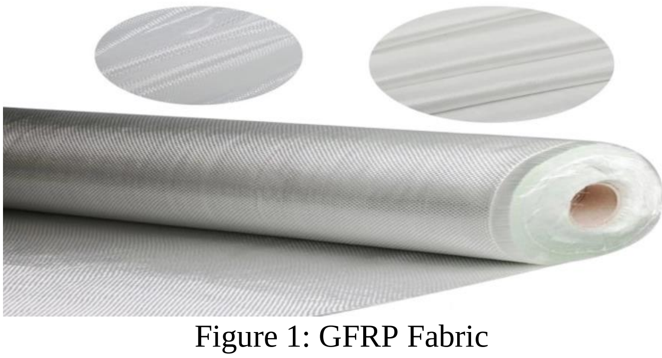

Figure 1: GFRP Fabric

Mechanical Properties of Steel Material

The mechanical properties of the Stone material were entered into the SAP 2000 program as follows.

Mass and Weight of Material:

1- Unit Volume Weight = 7849.0476 kgf/m^3,

2- Unit Volume Mass = 7851.72 kgf/m^3.

Mechanical Properties of Material:

1- Elasticity Module:

E1 = 2,1*10^5 kgf/mm2

2- Poison Rate:

U12 = 0,3

Mechanical Properties of GFRP Material

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 = 1938.12 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'dir.
2- Poison Rate:
U12 = 0.25
U13 = 0.25
U23 = 0.25.

Description of Steel Silo

First, the features of the Steel silo and the properties of the GFRP material were entered into SAP 2000 program. In this study, GFRP material will be applied to the entire surface. Thus, all thin cracks on surface will be closed. The diameter of steel silo is 4 m, while the height of steel silo is 12 m, the used steel type is St52. Steel thickness of the silo is 0.005 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.

Steel silo and GFRP's wall thicknesses used in this research article are given in Table 1.

Table 1. Table captions should be centred and placed above the table.

Material Name	Thickness (mm)
Steel Silo	5
GFRP	2

Results and Discussion

For the present condition and the state after reinforcement, the analysis was done using the finite element method in this section. The research was examined under several categories, and the results were given. In both cases, the mode shapes and the period values of the mode are given separately and compared.

Analysis of Steel Silo Without GFRP

The 3D finite element model of the Steel silo was created with the SAP 2000 program. Steel silo's finite element model without GFRP results is given in figure 2.

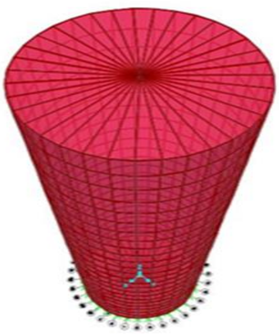

Figure 2: Steel Silo Finite Element Model without GFRP

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

Table 2. Period of Steel Silo without GFRP

Mode No	Period (s)
1	0,099457
2	0,090705
3	0,082066
4	0,062099
5	0,059542

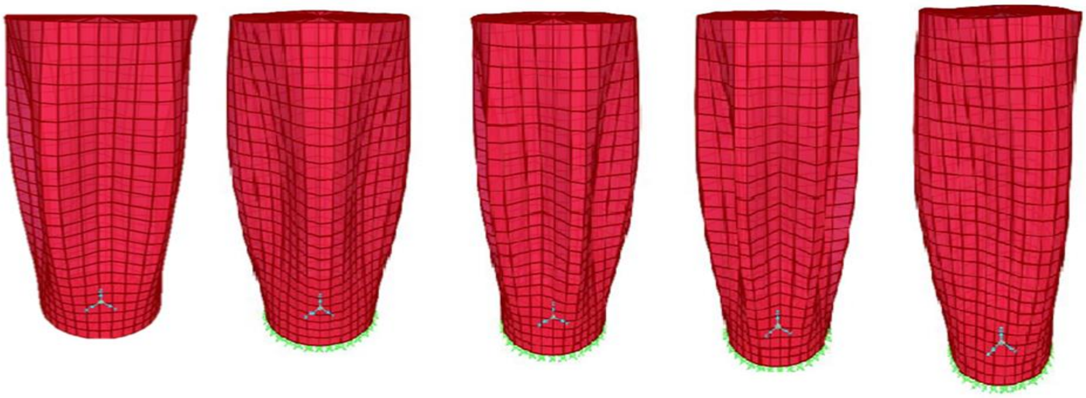

Figure 3: Respectively Mode Shapes of Steel Silo without GFRP

Analysis of Steel Silo With GFRP

The reinforced state is depicted in Figure 4 by the finite element model of the steel silo; GFRP reinforced. As a reinforcement mechanism, the GFRP fabric method is applied in this paper. The thickness of the GFRP fabric is 2 mm. GFRP fabric is applied to the entire outer surface. SAP2000 package program was used to obtain the analysis data.

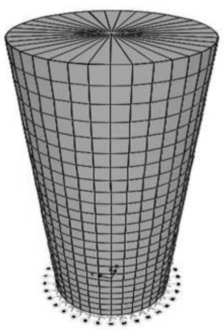

Figure 4: Steel Silo Finite Element Model with GFRP

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

Table 3. Periods of Steel Silo with GFRP

Mode No	Period (s)
1	0,092249
2	0,089006
3	0,073224
4	0,059826
5	0,05442

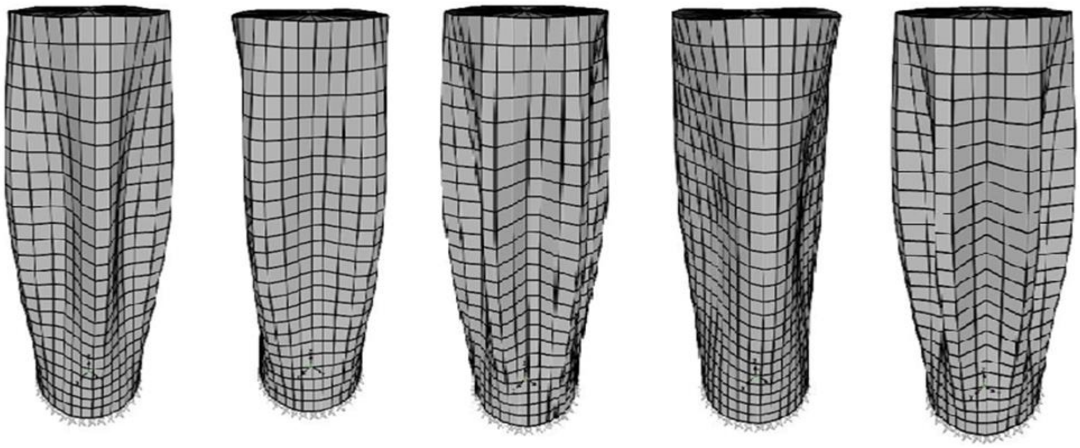

Figure 5: Respectively Mode Shapes of Steel Silo with GFRP

Comparison of Analysis Results

Table 4 contrasts the period of the model without GFRP and the model with GFRP. Following table shows the comparison period of the GFRP model without and with the GFRP model.

Table 4. Comparison Periods Before Applying GFRP Model and Applying GFRP Model

Mode no	Difference (s)	Difference (%)
1-1	-0,007208	7,25%
2-2	-0,001699	1,87%
3-3	-0,008842	10,77%
4-4	-0,002273	3,66%
5-5	-0,005122	8,60%

Torsions were observed in the all-mode shapes.

CONCLUSIONS

In this study, as a result of the reinforcement made by wrapping 2 mm thick GFRP fabric into the 5 mm thick Steel Silo structure, the percentage changes in the parameters of the structure are listed as below.

In the mode 1, the period difference between non-GFRP and GFRP status was obtained as -0,007208s. The effect of GFRP reinforcing as a percentage was determined as 7,25%.

In the mode 2, the period difference between GFRP and non-GFRP status was obtained as -0,001699s. The effect of GFRP reinforcing as a percentage was determined as 1,87%.

In the mode 3, the period difference between GFRP and non-GFRP status was obtained as -0,008842s. The effect of GFRP reinforcing as a percentage was determined as 10,77%.

In the mode 4, the period difference between GFRP and non-GFRP status was obtained as -0,002273s. The effect of GFRP reinforcing as a percentage was determined as 3,66%.

In the mode 5, the period difference between GFRP and non-GFRP status was obtained as -0,005122s. The effect of GFRP reinforcing as a percentage was determined as 8,60%.

With the reinforcement of the Steel silo with GFRP, a decrease in the periods is clearly visible. Especially when the dominant period is analyzed, a 10,77 percent decrease is observed. It is also known that the reduction in periods removes the structure from the resonance range and increases the stiffness.

Torsions were observed in the mode shapes for both models (GFRP and non-GFRP).

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 which is a single layer application. Thus, the most fundamental effects have been revealed.

In the light of all these findings, GFRP reinforcement method can be used in reinforcing Steel Silos.

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