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Performance of Thin Cylindrical Shells with GFRP Fibres Subjected to Compression Forces

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Abstract

Shells are objects considered as materialization of curved surface. A research has been carried out to study the behavior of thin cylindrical shell. The fiber helps to transfer the loads to the internal micro cracks. In order to study the behavior of thin cylindrical shells, literatures have been given in this report. The load carrying capacity of the thin cylindrical shells with and without GFRP has been calculated using experimental analysis. And also maximum deflection has been calculated using experimental analysis. The experimental work has been made with normal cylindrical shell as well as additionally reinforced with GFRP. For 12 numbers of specimen was load was applied as axial compression on the plan surface of the shell. The shell specimens are tested with 7 days and 28 days respectively. The ultimate load carrying capacity of the cylindrical shell is increased when GFRP is used. Finally to compare the ultimate load carrying capacity of thin cylindrical shells with and without GFRP fibres. In practical applications we frequently encounter problems in which a circular cylindrical shell is submitted to the action of forces distributed symmetrically with respect to the axis of the cylinder.

Keywords: *Cylindrical Shell, GFRP fibres, Ultimate Load Carrying Capacity, Deflection.*

1. Introduction

Shell structures find application in many fields of engineering, notably civil, mechanical and aeronautical disciplines. In the past 100 years, considerable effort has been expended on the development of rigorous theories both general and specialist-to describe the behavior of shells in the elastic range as realistically as possible.

The spatially curved surface of shell structures can be classified in several ways. For shell structures it is convenient to make a classification according to Gaussian curvature. The Gaussian curvature of a three dimensional surface is the product of principal curvatures, which are defined as the maximum and minimum curvature of a certain surface. The principal curvatures can be found by intersecting shell by an infinite number of planes normal to the shell surface at an arbitrary point and determining the two planes for which the secant with the surface has a maximum curvature and a minimum curvature. The principal curvatures are, by definition, orthogonal to each other. The product of the principal curvatures is either positive, zero or negative.

Classification in Gaussian curvature therefore means a classification in surfaces with

a. Positive Gaussian curvature (synclastic).

b. Zero Gaussian curvature (monoclastic).

c. Negative Gaussian curvature (anticlastic).

2. Types of Fibres

In this section, the most commonly used commercial fibres are introduced. The manufacture of these fibres, their properties and applications are briefly discussed. GFRP fibres used in this research are mainly discussed in detail.

a. Glass Fibres
b. Carbon fibres
c. Steel fibres
d. Synthetic fibres
e. Natural fibres

2.1 Glass Fibres

Since the late 1960s, alkali-resistant glass fibres have been used for reinforcing cement because of their excellent engineering properties. Generally glass fibres have from 25 to 35 mm length. These fibres have high tensile strength (2 – 4 GPA) and elastic modulus (70 – 80GPa) but have brittle stress-strain characteristics (breaking at 2.5 – 4.8% elongation). Claims have been made that up to 5% glass fibre by volume has been used successfully in sand, cement and mortar without balling. However, the limitation of glass-fibre products is their durability because of loss of strength when exposed to outdoor environments.

2.2 Glass Fibre reinforced concrete

Glass fibre–reinforced concrete (GFRC) is a type of concrete which basically consists of a cementitious matrix composed of cement, sand, coarse aggregate, water, polymer and admixtures, in which short length glass fibres are dispersed. In general, fibres are the principal load-carrying members, while the surrounding matrix keeps them in the desired location sand orientation, acting as a load transfer medium between the fibres and protecting them from environmental damage. In fact, the fibres provide reinforcement for the matrix and other useful functions in fiber-reinforced composite materials. Glass fibres can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths. Glass fibres have large tensile strength and elastic modulus but have brittle stress strain characteristics and low creep at room temperature. Glass fibres are usually are usually round and straight with diameters from 0.005 mm to 0.015 mm**.** Different types of glass fibres are available in the market having different length, diameter and aspect ratio. In the present study alkali resistant glass fibres were used throughout the experiments. The study comprises of a comparative study of some of the properties of concrete for two different grades of concrete by varying the percentages of fibre.

2.3 Benefits of GFRP

The benefits of GFRP rebar are as follows:

- **Corrosion resistance**-When bonded in concrete it does not react to salt, chemical products or the alkali in concrete. As GFRP is not manufactured from steel, it does not rust.
- **Superior tensile strength** - GFRP rebar produced by the pultrusion process offers a tensile strength up to twice that of normal structural steel (based on area).
- **Thermal expansion** - GFRP rebar offers a level of thermal expansion comparable to that of concrete due to its 80% silica content.
- **Electric and magnetic neutrality** - As GFRP rebar does not contain any metals, it will not cause interference with strong magnetic fields or when operating sensitive electronic equipment or instrument.
- **Thermal insulation** - GFRP rebar does not create a thermal bridge within structures.

- **Lightweight** - GFRP rebar is a quarter the weight of steel rebar of equivalent strength. It offers significant savings in transportation and installation.

- **Reinforced concrete exposed to corrosive environments** - Car parking structures, bridge decks, parapets, curbs, retaining walls, foundations, roads and slabs.

3. Objective and Scope of the Project

a. To improve the compressive strength of cylindrical shells by adding GFRP fibres with concrete.
b. To reduce the lateral deflection of the compression members using GFRP fibres.
c. To determine the ultimate load bearing capacity.

4. Base Papers

Bhasker Perumandla et al (2013) A detailed experimental study was undertaken to investigate the buckling behavior of composite GFRP cylindrical shells subjected to in plane compressive load. The size of the GFRP thin cylindrical shells were designed parametrically and chosen as 300mm effective length, 1.5mm thickness with 300mm diameter. The +45°/-45° ply sequence was taken in composite laminated cylindrical shell analysis. The linear and nonlinear buckling analysis was performed for the above designed size of the composite cylindrical shell. The purpose build mandrel of 300mm diameter was used to make the cylindrical shell of 1500mm length with 1.5mm thickness. The cured cylindrical shell was extracted from the mandrel using specially designed hydraulic ficture.Five numbers of specimens with each 300mm length cylindrical shell were prepared for testing. In ANSYS, a subspace iteration technique is employed to extract the Eigen values and the corresponding Eigen vectors. The cylindrical shell was subjected to static axial compression under load control by a hydraulically operated compression testing machine of 100KN capacity. The specimen was placed between the two heads of the compression testing machine, which has a moving bottom head and a fixed top head. In order to accurately ascertain the axial load applied on the specimen, a load cell was placed between the specimen and the top head. When the load reached 56 KN, the shell buckled suddenly with a loud noise.

E. Eglitiset al (2010) This experimental and numerical study focuses on the buckling problem of cylindrical composite shells under pulse loads. Fifteen cylindrical specimens have been produced of glass fiber fabric reinforced plastic (GFRP). The specimens have diameters D of 300 and 500 mm and lengths L varying from 400 to 660 mm. Each specimen is composed of four layers of 290 g/m2 E-glass fiber fabric and Polylite 440 polyester resin. The load-shortening curves and post-buckling shapes are recorded. The dynamic buckling tests have been performed under displacement control, using a triangular load pulse. The maximum loading rate of 170 mm/s, loading rates of 140 mm/s, 70 mm/s and 40 mm/s were used. Finite element programme ABAQUS were adopted. A consistent increase of the buckling load with the increase of loading rate, resulting in all DLFs being greater than 1. The loading frequency is close to the lowest natural frequency of the structure, or the load is applied suddenly, the buckling strength can be significantly less than under static loading.

MojtabaYazdani et al (2009) The buckling behavior of thin-walled GFRP cylindrical shells, the specimens were fabricated from continuous glass fiber using a specially-designed filament winding machine. The buckling behaviors of unstiffened shells and stiffened shells with lozenge, triangular and hexagonal grids were studied under quasi-static axial loading at room temperature. Due to the thin skin of the shells, all specimens first experienced a general buckling mode as well as barreling under the applied loading. The specimens were fabricated from E-glass fiber and room temperature- curing epoxy resin using a special-designed filament winding machine. The fibre winding of specimen like 3 clockwise and 3 counter-clockwise helical ribs, while in the triangular and hexagonal grids there were 2 hoop rings. The specimens were characterized by an external diameter of 140 mm and an overall length of 314 mm. Axial loading, an INSTRON 5500R test machine with a capacity of 200 KN was used. Each specimen was tested under pure axial compression based on the ASTM D6641 standard with a loading rate of 1.3mm/min. The shells with hexagonal and triangular grids exhibited maximum critical buckling load compared to unstiffened shells and shells with lozenge grids. In very small skin thickness, unstiffened shells showed highest specific buckling load compared to other specimen. The hexagonal and triangular grids exhibited higher failure displacement comparing to that of the lozenge grids.

A. Zingoni et al (2013) They have been investigated the buckling behaviour of vertical concrete arch dams which are curved in plan. The present study makes use of FEM modelling to determine the influence of key parameters on the critical buckling pressure of cylindrical and elliptic-paraboloidal arch dams. The actual mathematical shape of the arch does not have significant effect on the buckling strength. But other geometric properties (such as shell thickness t, rise ratio h/a and aspect ratio b/a) have a far greater effect. By comparing the results for the elliptic paraboloid with those for the parabolic cylindrical arch, the benefits of double curvature are evaluated. The Buckling pressures are seen to decrease sharply with increasing relative depth (i.e. aspect ratio) of the arch dam, the rate of decrease becoming slower as b/a gets larger.

5. Experimental Work

5.1 cylindrical specimens

Cylinders shell is having outer diameter of 300 mm and inner diameter of 240 mm, so the shell is having 30 mm thickness and height of 400mm, 600mm. The following Figure: 1 shows the specimen of cylindrical shell.

Fig:1 casting specimen

5.2 Axial Compression Test on Cylindrical Shell

Axial compression on cylindrical shell is same as loading the cylinder axially on top and bottom of shell. A deflectometer is placed to take the deflection of cylindrical shell. Two steel rings are attached at top and bottom of the specimens. Strain gauges are attached on four sides of specimen to measure the lateral deflection using strain indicator. The Figure: 2 show the testing of specimen.

Fig: 2 Testing Specimen

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5.3 Simply Supported Test

Specimen is placed in compression machine as simply supported and load was applied as point load at Centre along its length. A deflectometer is placed to take the deflection at Centre of cylindrical shell. The support is adjustable, so it can be tested in different size of specimen. The following Figure: 3 show the testing of various specimens.

Fig: 3 simply supported testing specimen

6. Experimental Test Results

6.1 Axial Compression Test Result

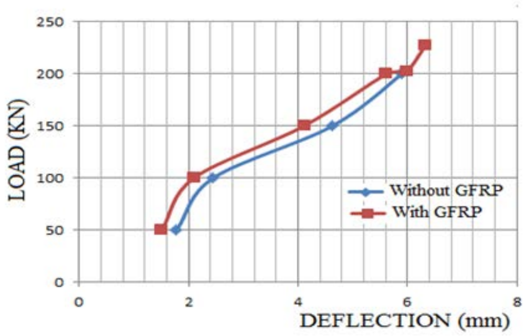
Axial compression on cylindrical shell is same as loading the cylinder axially on top and bottom of shell. A deflectometer is placed to take the deflection of cylindrical shell.

Table 1: ultimate load of without and with GFRP specimen (7 days)

Ultimate load (KN)	***Without GFRP***	**With GFRP**
Sample 1	200	230
Sample 2	205	225

Load carrying capacity of shell specimen (7 days) without GFRP is 202.5KN.

Load carrying capacity of shell specimen (7days) with GFRP is 227KN.



Graph 1: Load vs. Deflection for without and with GFRP specimen (7days)

Maximum deflection for without GFRP specimen (7days) =5.913 mm

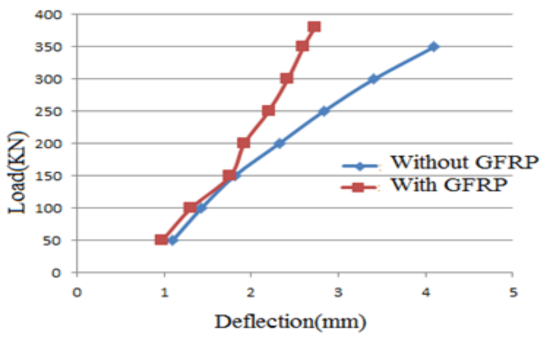
Maximum deflection for with GFRP specimen (7days) =6.33 mm.

Table 2: ultimate load of without and with GFRP specimen (28days)

Ultimate load (KN)	***Without GFRP***	**With GFRP**
Sample 1	354	382
Sample 2	346	378

Load carrying capacity of shell specimen (28 days) without GFRP is 350KN.

Load carrying capacity of shell specimen (28days) with GFRP is 380KN.



Graph 2: Load vs. Deflection for without and with GFRP specimen (28days)

Maximum deflection for without GFRP specimen (28days) =4.10 mm.

Maximum deflection for with GFRP specimen (28days) =2.73 mm.

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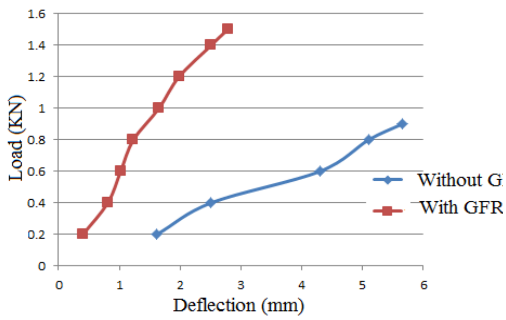
6.2 Simply Supported Test Results

Specimen is placed in compression machine as simply supported and load was applied as point load at Centre along its length. A deflectometer is placed to take the deflection at Centre of cylindrical shell.



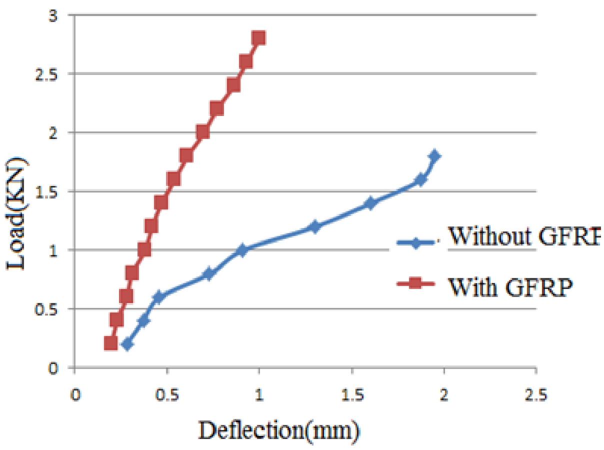
Graph 3: Load vs. Deflection for without and with GFRP specimen (7days)

Maximum deflection for without GFRP specimen (7days) =5.65 mm.

Maximum deflection for with GFRP specimen (7days) =2.78 mm.

Table 3: ultimate load of without and with GFRP specimen (7 days)

Ultimate load (KN)	***Without GFRP***	**With GFRP**
Sample 1	0.9	1.5



Graph 4: Load vs. Deflection for without and with GFRP specimen (28days)

Maximum deflection for without GFRP specimen (28days) =2.2 mm.

Maximum deflection for with GFRP specimen (28days) =1.0 mm.

Table 4: ultimate load of without and with GFRP specimen (28 days)

Ultimate load (KN)	***Without GFRP***	**With GFRP**
Sample 1	2.0	2.8

7. Conclusion

a. In axial compression test the ultimate load carrying capacity is 202.5 KN without GFRP and 227.5 KN with GFRP for 7days. Similarly, the ultimate load carrying capacity is 350 KN without GFRP and 380 KN with GFRP for 28days, the load has been increased by 26%, when using GFRP.

b. In axial compression test the deflection is 5.913mm without GFRP and 5.730mm with GFRP for 7days. Similarly the deflection 4.10mm without GFRP and 2.73mm with GFRP, the deflection has been decreased by 0.32 times, when using GFRP.

c. In simply supported the ultimate load carrying capacity is 0.9 KN without GFRP and 1.5 KN with GFRP for 7days. Similarly the ultimate load carrying capacity is 2.0 KN without GFRP and 2.8 KN with GFRP for 28days. Because of using GFRP the load has been increased 0.4 times.

d. Deflection in simply supported test has been decreased by 0.7 times. When using GFRP.

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