



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 8, August 2022

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.118

 9940 572 462

 6381 907 438

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# Comparative Study of Non-Linear Finite Element Analysis and Experimental Analysis of Parabolic Arch Wrapped With CFRP under Monotonic Loading

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**ABSTRACT:** Many researchers have carried out extensive investigations regarding structural behaviour of the advanced composites as columns, as flexural members and as structural members subjected to combine bending and axial thrusts. In spite of these important contributions, it should be noted, however, that most of the past studies have been conducted on straight members. Very few works have been conducted on curved members. For curved members the compression axial load in most circumstance is predominant. Since FRP wrapped concrete is notable for its high resistance against axial compression and bending moments and its construction with ease and economy, such a structural composite provides an effective alternative for conventional curved or arch-like structures. Consequently, there is a highly urgent need to understand the behaviour of this type of composite arch. In present research study for the experiment work wrapping technique is used. Two specimens are constructed one is parabolic concrete arch and second one is parabolic concrete arch wrapped with CFRP. Both the arches having size of cross-section 150 x 150 mm and 1.1 m centre to centre and 350 mm in total height. Measured maximum load carried by specimen and observed deflection at maximum load carried in experimental work. For the analytical work Finite Element Analysis is done by using ABAQUS software.

**KEYWORDS:** ABAQUS, Finite Element Analysis, Parabolic Arch, CFRP Wrap.

## I. INTRODUCTION

Fibre-reinforced polymer FRP firstly emerged as an innovative and efficient hybrid system is gaining ever growing popularity in civil engineering constructions, such as high-rise buildings, sport stadiums and long span bridges, primarily due to their superior performance. Among the advantages of this new structural composite, the FRP jacket can substantially enhance its load carrying capacity, chemical resistance and ductility, with considerable reductions in construction weight, cost and time. Many researchers have carried out extensive investigations regarding structural behaviour of the advanced composites as columns, as flexural members and as structural members subjected to combine bending and axial thrusts. In spite of these important contributions, it should be noted, however, that most of the past studies have been conducted on straight members. Very few works have been conducted on curved members. For curved members the compression axial load in most circumstance is predominant. Since FRP wrapped concrete is notable for its high resistance against axial compression and bending moments and its construction with ease and economy, such a structural composite provides an effective alternative for conventional curved or arch-like structures. Consequently, there is a highly urgent need to understand the behaviour of this type of composite arch. To make the composition of FRP and concrete wrapping technique is used in the present research. For wrapping CFRP fabric material is used. The fabric sticks to the concrete by using an adhesive material.

## II. RELATED WORK

In this study Ying Wen, Jing-guang Teng [3] are investigated an numerical model for modelling the behaviour of FRP tube confined concrete arch is developed, which included a finite element model composed of stepwise beam-column elements and stress-strain models for both confined concrete and external FRP tube. Co-rotational formulation is used to describe the large deformation effect by using OPENSEES Software.

Observed experimental results with Abaqus laboratory test carried out by T.Tejaswini et al. [6] on a beam of M30 grade of under, over, balanced sections. From the analytical investigation author observed that under reinforced ratio is the best type of reinforcement ratio among the other since it shows greatest warning zone before failure.

Kumar and Chowdary [7] the computation of membrane stresses and deflection corresponding to the applied loads on RCC beam were carried out using the standard program Abaqus. Abaqus program used to model the behaviour of RCC beam. The study revealed that FE analysis using proposed model can be applied to explore dynamic behaviour of structural element subjected to impact vibration.

Habib et al.[14] This paper investigated the bending response of CCTs for buried arch bridge structures. The thin-walled hybrid composite tubes developed at the University of Maine are fabricated from a combination of E-glass and carbon fiber braid infused with vinyl ester resin. . Three straight beams and four arches were tested in the laboratory to determine load–deformation and load–strain response under pseudo-static loading. Test results were generally consistent. The arch specimens exhibited a residual capacity of approximately 80% of their peak load resistance recorded at initial failure. Two additional arches were loaded with 2,000,000 cycles of fatigue loading and no significant post-fatigue strength reduction as observed. A nonlinear beam finite-element model was implemented that accounts for variable confinement of the concrete by the FRP shell, and shown to accurately predict the load–deformation, load–curvature and capacity of the tested arches.

Anand et al. [15] Investigated behaviour of RC beam retrofitted with CFRP. 12 beams were casted, Among 12 beam specimen 3 beam are tested for maximum load capacity. Remaining 9 beams are distressed by 60% of average ultimate load capacity of 3 control beam. Three beams are wrapped completely by CFRP, three are wrapped at middle and three are wrapped at bottom. The ultimate load obtained for control beam is 75KN, completely wrapped beam has an ultimate load of 114.5KN, middle wrapped beam has an ultimate load of 104.93KN, bottom wrapped beam has an ultimate load of 89.98KN. Completely wrapped beam carries maximum load compared to other specimens.

### III. METHODOLOGY

Detailed study carried related to arches for experimental and analytical work. Created a problem statement, arrange materials for experimental work and casted two arch specimen casted one for concrete arch test and another for concrete arch complete wrapped with CFRP. After 28 days of curing one specimen wrapped with CFRP fabric by using Adhesive SikaSikadur 330IN. both the specimen tested in the loading frame of capacity 150kN. After experimental work analysed same specimen in ABAQUS software. Compare the results of experimental and analytical work.

### IV. EXPERIMENTAL RESULTS

#### 1. Problem Statement

Fixed parabolic concrete arch subjected to a downward point load at the crown will be analysed. These arches has span of 1.4 m with a central height of 300mm. Concrete grade is M30. Wrapped with CFRP Sheet.

#### 2. Mix Design Results.

Mix design calculated by referring IS456:2000 for M30 grade of concrete and calculated material quantity which is given in table 1.

Table 1. Mix Design Ingredient Quantity

S. No.	Materials	Quantity (kg/m <sup>3</sup> )
1	Cement	425
2	Water	153
3	20mm Aggregate	765
4	10 mm Aggregate	546
5	Crushed Sand	721.7
6	Admixture	3.40

### 3. Testing of Concrete Arch Wrapped with CFRP

The Specimen Tested after curing of 28 days and wrapped with CFRP Fabric Sheet by dry method using adhesive SikaSikadur 330IN. Figure 1 a,b,c shows the casting, wrapping and testing of arch specimen. Tested in Loading Frame having capacity of 150 kN.

The test results are shown in the table 2. And Figure 2 shows the load vs. Deflection Curve.



Figure 1a Casting of Specimen



Figure 1b Wrapping of Specimen



Figure 1c Testing of Specimen

Table 2 Load Carrying Capacity for Arch Wrapped Completely

Sr. No.	Title	Load Carried (kN)	Moment (N.mm)	Flexure N/mm <sup>2</sup>	Deflection (mm)
1	Concrete Arch	59.8	3083437.5	23.47	6

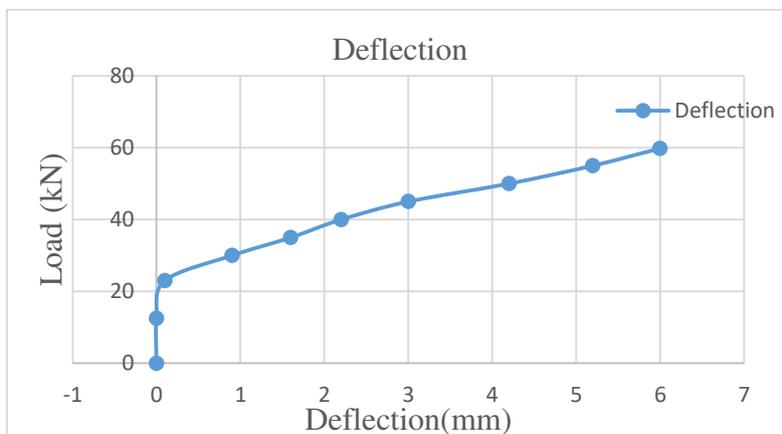


Figure 2 Load vs. Deflection Curve of CFRP Wrapped Concrete Arch

Figure 1. Shows the load vs. deflection curve graph for concrete arch wrapped with CFRP. From the Experiment, The concrete arch specimen is tested on the loading frame having capacity of 150 kN. As the load applied on the arch specimen is increases at the rate of 0.4 kN/sec. The type of application of loading is single point load at the crown of arch. Obtained Flexure strength of CFRP wrapped concrete arch specimen is 23.47 N/mm<sup>2</sup> after arch specimen collapsed after the Maximum load carried which is 59.8 kN. At the maximum load the observed deflection is 6 mm.

### V. ANALYTICAL RESULTS

The Concrete arch wrapped with CFRP is modelled in ABAQUS for Finite element analysis. Displacement based analysis is done and obtained max load carrying capacity.

Table 3 shows the relative values of load and deflection obtained for CFRP wrapped arch under monotonic loading from FE analysis in ABAQUS software. The table is created by the Graph shown in figure 3 For the 7mm deflection 63.58 kN load is carried by concrete arch wrapped with CFRP.

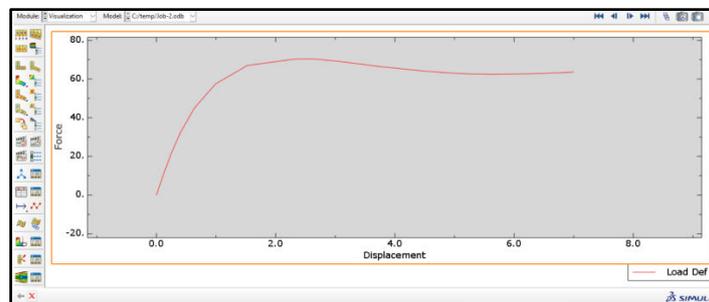


Figure 3 Load Deflection curve

Table 3 Load Deflection Values for CFRP arch

Deflection (mm)	Load (kN)
0.5	37.90
1	57.65
1.5	66.63
2	68.98
2.5	69.81
3	71.16
3.5	67.97
4	65.97
4.5	64.11
5	62.86
5.5	62.50
6	62.60
6.5	62.94
7	63.58

### VI. CONCLUSION

Finite Element Analysis of Concrete parabolic arch wrapped with CFRP achieved load carrying capacity is 62.60 kN for the 6mm deflection. Similarly From experimental results maximum load carried by concrete parabolic arch wrapped with CFRP is 59.8 kN and observed deflection is 6mm maximum. The difference between the analytical and experimental work is 4.58%. The load carrying capacity at 7mm is 63.58 kN achieved. The difference between experimental and Analytical analysis is acceptable.



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