EFFECT OF CORNER RADIUS AND CONFINEMENT LAYERS ON BEHAVIOUR OF RC COLUMNS

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DEPARTMENT OF CIVIL ENGINEERING

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EFFECT OF CORNER RADIUS AND CONFINEMENT LAYERS ON BEHAVIOUR OF RC COLUMNS

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Civil Engineering

(Computer Aided Structural Analysis and Design)

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May 2012

Declaration

This is to certify that

i) The thesis comprises my original work towards the Degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

Sushil S. Sharma

Certificate

This is to certify that the Major Project entitled “EFFECT OF CORNER RADIUS AND CONFINEMENT LAYERS ON BEHAVIOUR OF RC COLUMNS” submitted by Mr. Sushil S. Sharma (10MCLC15), towards the partial fulfilment of the requirement for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University, Ahmedabad, is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Abstract

Existing reinforced concrete (RC) columns may be structurally deficient due to variety of reasons such as improper transverse reinforcement, flaws in structural design, insufficient load carrying capacity, etc. A poorly confined concrete column behaves in a brittle manner, leading to sudden and catastrophic failures. Carbon/Glass(G) Fibre reinforced polymer (FRP) confinement can be effectively used for strengthening the deficient RC columns.

The effectiveness of FRP wrapping for RC columns mainly depends upon corner radius of the specimens as well as number of FRP layers used for the confinement. An attempt has been made hereby to investigate the experimental behaviour of GFRP wrapped small scale square RC columns with varying corner radii. Experimentally evaluated behaviour of GFRP wrapped RC columns is compared with the performance observed for non-wrapped RC columns. Experimental behaviour of RC columns is further compared with analytical results.

27 RC columns having cross-sectional dimensions 125mm $\times$ 125mm and length of 1200mm have been cast and tested under axial compression. Three columns are unwrapped and have been designated as control specimens. Three columns each with corner radii equivalent to less than cover (15mm), equal to cover (25mm) and greater than cover (35mm), are wrapped with one & two layers of GFRP, respectively. To avoid a premature rupture of the GFRP composite, remaining six columns with corner radius of 5 mm have been wrapped with one and two layers of GFRP, respectively.

Analysis and design of control RC column has been done according to IS 456:2000 and ACI 318M - 08 provisions, respectively. IS 456:2000 does not cover provisions pertaining to design of FRP wrapped columns. The FRP wrapped columns are designed using provisions of ACI 440.2R - 08. To maintain adequate correlation, the

control columns are further designed based on provisions of ACI 318M - 08.

Measurements taken during testing included axial compressive strength, displacement, axial strain, lateral strain, failure modes and crack patterns. Axial load has been applied from bottom of the column with the help of hydraulic jack. Displacement and axial strain measured with the help of LVDT and lateral strain measured with the help of P3 strain indicator and recorder are observed for the columns. Interval is kept 10 kN constant up to the complete failure of the column specimen. Percentage increment in ultimate failure load is ranging from 8.10 % to 149.45 % for all wrapped columns compared to control columns. GFRP wrapped column goes under higher axial displacement in order to gain higher compressive strength over control column. Lateral strain is more at the mid side of specimen and then reduces at starting of curvature to center of curvature for the columns. From the failure of column, it is clearly shown that the rupture of GFRP sheet transfers from edges (zone 1) to mid of side face (zone 2) of the specimen.

The results showed that smoothening of the edges of square cross-section play a significant role in delaying the rupture of the FRP composite at the edges. Increasing the number of GFRP layers increases the axial compressive strength of the specimens, but the strength increase is not in linear relation with the number of GFRP layers. From results it is interpreted that the corner radius equal to concrete cover gives better results in terms of ultimate load carrying capacity than the corner radius less than cover and more than cover.

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I cannot present this work without first expressing my appreciation and gratitude to **Mr. Himat Solanki** and **Dr.U.V.Dave**, for their valuable guidance and constant encouragement at every stage of progress of the major project work. It was a very pleasant and inspiring experience for me to work under them.

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Abbreviation, Notation and Nomenclature

R_c .... Corner radius

l_{ex} .... Effective length in respect of the major axis

l_{ey} .... Effective length in respect of the minor axis

D .... Depth in respect of the major axis

b .... Width of the member

h .... Long side cross-sectional dimension of rectangular compression member

P_u .... Axial load on the member

f_{ck} .... Characteristic compressive strength of the concrete

f'_c .... Specified compressive strength of concrete

A_c .... Area of concrete

A_g .... Gross area of concrete section

f_y .... Characteristic strength of the compression reinforcement

A_{sc} .... Area of longitudinal reinforcement for columns

A_{st} .... Total area of nonprestressed longitudinal reinforcement

ϕ .... Strength reduction factor

ρ_g .... Ratio of area of longitudinal steel reinforcement to cross-sectional area of a compression member

f'_{cc} .... FRP-confined concrete compressive strength

P_n .... Nominal compressive strength of a short concrete column

P_{cn} .... Nominal compressive strength carried by the concrete

P_{sn} .... Longitudinal reinforcing steel bars

ϕ_c .... Resistance factors for concrete

ϕ_s .... Resistance factors for steel

N_b .... Number of layers of FRP

ϕ_{frp} .... Resistance factor for the FRP

$frpu$ .... Ultimate tensile strength of the FRP

t_{frp} .... Thickness of the FRP

C_c .... Clear cover
C_E .... Environment reduction factor
$f_{fu}*$ .... Ultimate tensile strength
$\varepsilon_{fu}*$ .... Rupture strain
f_l .... confining pressure due to the FRP
n .... Number of plies
ψf .... FRP strength reduction factor
E_f .... Modulus of elasticity
t_f .... Thickness of layer
k_ε .... Efficiency factor
S0R0 .... Control column
S1R0 .... One layer of GFRP sheet for column having 5 mm corner radius
S2R0 .... Two layers of GFRP sheet for column having 5 mm corner radius
S1R1 .... One layer of GFRP sheet for column having 15 mm corner radius
S2R1 .... Two layers of GFRP sheet for column having 15 mm corner radius
S1R2 .... One layer of GFRP sheet for column having 25 mm corner radius
S2R2 .... Two layers of GFRP sheet for column having 25 mm corner radius
S1R3 .... One layer of GFRP sheet for column having 35 mm corner radius
S2R3 .... Two layers of GFRP sheet for column having 35 mm corner radius
f_{cc} .... Mean compressive strength of GFRP confined concrete columns
f_{co} .... Mean compressive strength of the unconfined control columns

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Chapter 1

Introduction

1.1 General

Existing reinforced concrete columns may be structurally deficient for several reasons: substandard seismic design details, improper transverse reinforcement, flaws in structural design, and insufficient load carrying capacity. Over the last few years, there has been a worldwide increase in the use of composite materials for the rehabilitation of deficient reinforced concrete structures. One important application of this composite retrofitting technology is the use of fibre reinforced polymer (FRP) jackets or sheets to provide external confinement to reinforced concrete columns when the existing internal transverse reinforcement is inadequate. Reinforced concrete columns need to be laterally confined in order to ensure large deformation under load before failure and to provide an adequate load resistance capacity. In the case of a seismic event, energy dissipation allowed by a well-confined concrete core can often save lives. On the contrary, a poorly confined concrete column behaves in a brittle manner, leading to sudden and catastrophic failures [1].

With the development of technology, the use of high-strength concrete members has proved most popular in terms of economy, superior strength, stiffness, and durability.

With the increase of concrete strength, the ultimate strength of the columns increases, but a relatively more brittle failure occurs. The lack of ductility of high-strength concrete results in sudden failure without warning, which is a serious drawback. Previous studies have shown that addition of compressive reinforcement and confinement will increase the ductility as well as the strength of materials effectively. Concrete, confined by transverse ties, develops higher strength and to a lesser degree ductility.

In recent years, the composite materials, by their non-corrodibility, high stiffness and strength-to-weight ratios, have quickly appeared as innovative solutions adapted to the strengthening and the repair of civil engineering structures. The composite materials generally used are unidirectional carbon or glass fibre externally retrofitted to concrete by bonding. The resins used are epoxy. The confinement of concrete columns is thus an application where external wrapping by glass or carbon fibre reinforced polymers is particularly effective. This innovative technique is used for reinforcing old structures in the civil engineering field. Another attractive advantage of FRP over steel straps as external reinforcement is its easy handling. Thus, minimal time and labour are required for implementation. The application of FRP in the construction industry can eliminate some unwanted properties of high-strength concrete, such as its brittle behaviour. FRP is a durable material in normal exposure conditions and is capable of wrapping any shaped concrete sections.

1.2 Behaviour of RC Columns under Axial Compressive Loading

Concrete columns when confined by suitable arrangement of transverse reinforcement shows significant increase in both strength and ductility. When concrete column is subjected to compression load, it undergoes volumetric changes with a lateral increase in dimension due to progressive internal fracturing and bears out against the transverse reinforcement, which in turn exert a compressive reaction force on the concrete core. In this state the progress of internal fracturing is prevented, which in turn increases the strength and deformation capacity of concrete and therefore the main act of the lateral reinforcement is to produce a confined core. But as the confining action is more at the level of the ties and reduced along the length, entire core of the column do not remain effective throughout the length, Also the confining action is more at the region where there is longitudinal steel and reduced as the distance increase at the same level as shown Figure 1.1. The confinement provided in the form of hoops,

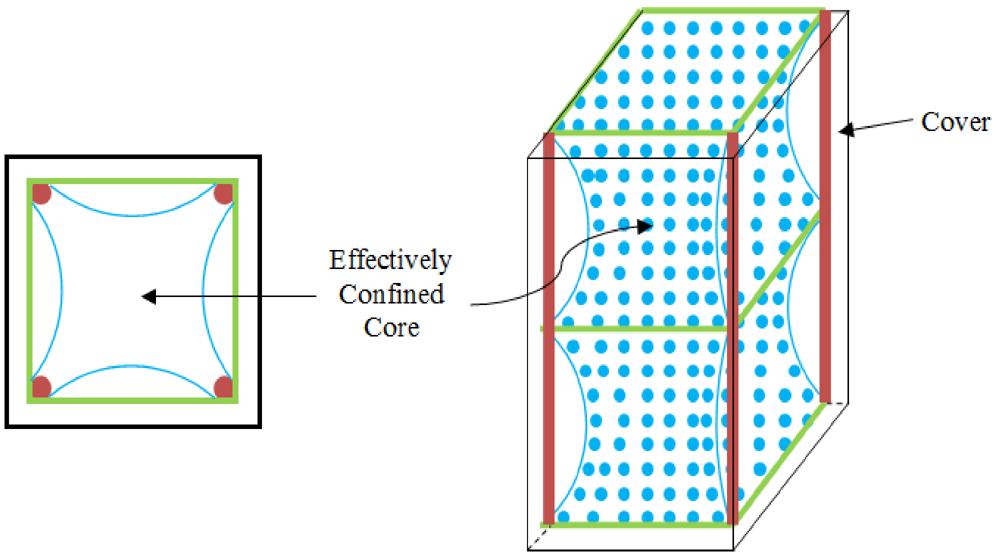


Figure 1.1: Development of confined core in column

spiral or ties is termed as passive confinement, as the confinement comes in to action when the concrete start to increase in volume due to progressive internal fracturing and bears out against the transverse reinforcement.

1.3 Behaviour of FRP-Confined Concrete under Axial Compressive Loading

A square column with rounded corners is shown in Figure 1.2. To improve the effectiveness of FRP confinement, corner rounding is generally recommended. Due to the presence of internal steel reinforcement, the corner radius R_c is generally limited to small values. Existing studies on steel confined concrete have led to the simple proposition that the concrete in a square or rectangular section is confined by the transverse reinforcement through arching actions, and only the concrete contained by the four second-degree parabolas is fully confined, while the confinement to the rest is negligible. These parabolas intersect the edges at 45°. While there are differences between steel and FRP in terms of providing confinement, the observation that only a part of the section is well confined is also valid in the FRP confinement. The reduced effectiveness of FRP jacket for a square or rectangular section than for a circular section has been confirmed by experimental results. Despite this reduced effectiveness, an FRP-confined square concrete column generally fails by FRP rupture [7].

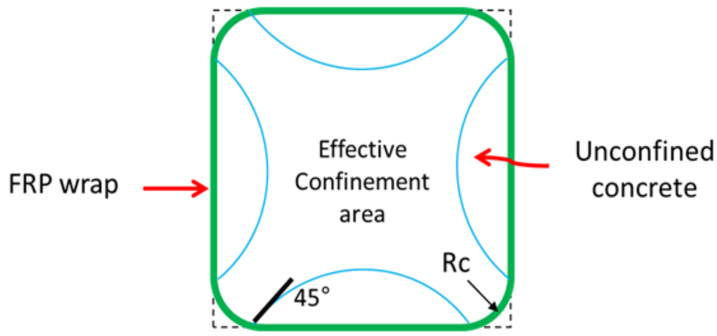


Figure 1.2: Effectively confined concrete in a square column

1.4 Research Significance

The use of externally bonded FRP composite for strengthening and repair can be a cost-effective alternative for restoring or upgrading the performance of existing concrete columns. Even though a lot of research has been directed towards circular columns, relatively less work has been performed on square and rectangular columns, to examine the effects of FRP confinement on the structural performance. However, a vast majority of all columns in buildings are square or rectangular. Therefore their strength and rehabilitation need to be given attention to preserve the integrity of building infrastructure.

Up till now a lesser amount of research has been carried out on effect of corner radius i.e. How much corner radius should be kept in square column, which is less than cover ($<$ cover), equal to cover ($=$ cover) or greater than cover ($>$ cover). As the more number of confinement layers increase the material cost, how many confinement layer should be provide which gives higher value of compressive strength.

1.5 Objectives of Study

The main endeavour of this study is to experimentally scrutinize the effects of upgrading the load carrying capacity of reinforced concrete square columns subjected to axial compression by confining with GFRP wraps. The objectives of the study are as follows:

1) To enhance the load carrying capacity of RC column by Strengthening using GFRP wrapping.

2) To evaluate axial load, vertical deflection, lateral strain, mode of failure and crack patterns of RC columns under axial compressive loading experimentally.

3) To evaluate the effect of the corner radius on the performance of GFRP confined

columns.

4) To study change in behaviour of RC columns when the corner radius is varied as 0 mm, 15 mm, 25 mm & 35 mm, respectively.

5) To study change in the ultimate strength of confined concrete columns when the number of confinement layers are varied from 1 to 2.

6) To compare experimental results with analytical results for the RC columns.

1.6 Scope of Work

In order to achieve above objectives, the scope of present study is considered as follows:

- Total twenty seven RC columns are planned to be cast in the laboratory. 3 columns are without wrapping, whereas remaining 24 columns are wrapped with GFRP composite. All the columns are wrapped in such a manner that the fibres remain in a hoop direction around the columns. Figure 1.3 shows the flowchart for variations employed in parameters of the present study.

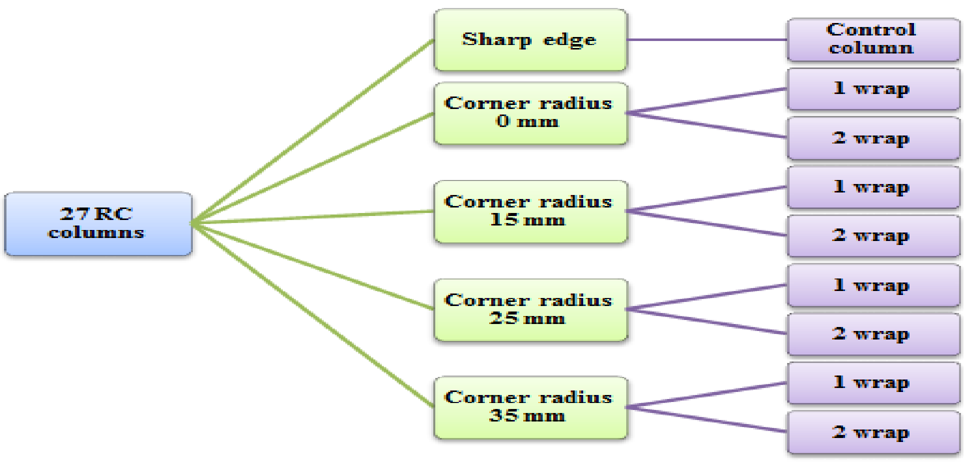


Figure 1.3: Flow chart for variation in parameters

- Variation in the corner radii has been employed for 18 columns. Corner radii of column included in present study are less than cover, equal to cover and more than cover, respectively.

- For each corner radius, the column specimens are to be wrapped by one layer and two layers of GFRP, respectively.

- Following measurements are planned to be taken during testing of the columns.

  a. Ultimate failure load

  b. Cracking pattern of wrapped and unwrapped columns

  c. Axial stress strain behaviour

  d. Maximum deflection

- Average result of three columns is to be considered as final result in terms of variation in above structural parameter for the columns.

1.7 Organization of Report

There are seven chapters included in this report. The contents of chapters are briefly described as follows:
Chapter 1 includes introduction, behaviour of RC columns under axial compressive loading and behaviour of FRP-confined concrete under axial compressive loading. The research significance, objectives of study and scope of work are also included in this chapter.

Chapter 2 discusses literature review. Many researchers have worked to improve capacity of column using FRP material. Investigations conducted on FRP wrapping and strengthening for deficient RC columns is presented in this chapter.

Chapter 3 consists of analysis and design of RC column with and without using GFRP sheet based on relevant codal provisions.

Chapter 4 explains the experimental work conducted in major project. It also highlights in detail the GFRP wrapping procedure, testing setup and instrumentation to be used during the testing of RC columns.

Chapter 5 includes results and discussion of failure load, deflection, and strain for all the column specimens in tabular form as well as in form of graphical representation. It also contains details about failure modes tested columns and comparison between experimental results with analytical results.

Chapter 6 consists of concluding remarks and future scope of work on basis of the work conducted in the major project.

Chapter 2

Literature Review

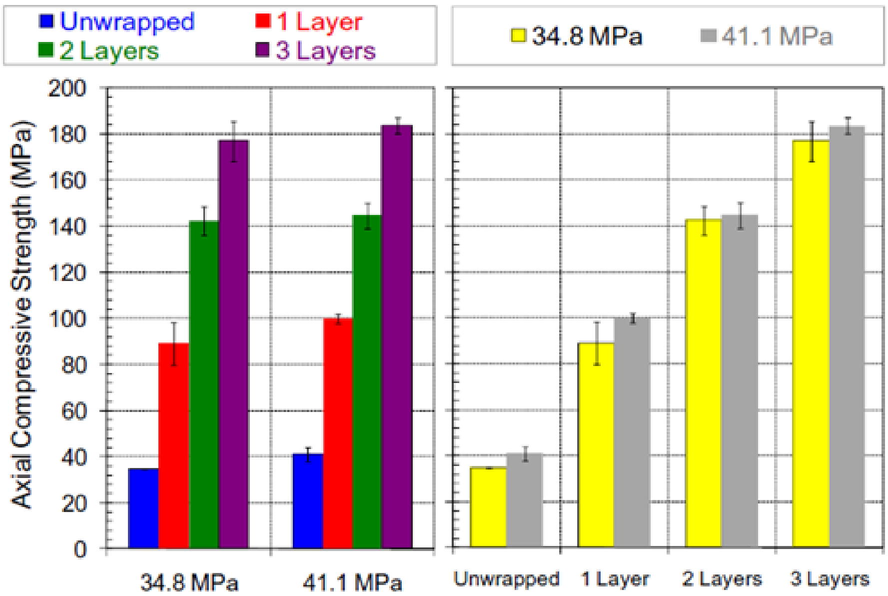
2.1 General

A brief review of experimental and analytical work related to RC Column strengthened using externally bonded FRP composites reported in literature is presented in this chapter.

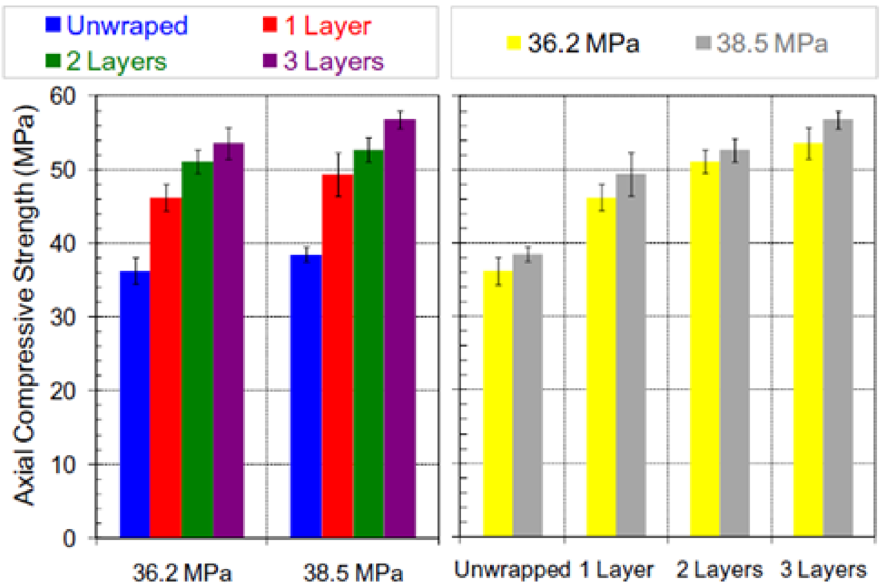
2.2 Experimental Work

Silva [**2**] performed tests on axially loaded square RC columns, with and without FRP jackets. Square cross-section was divided into three groups according to corner sharpness: R1 - sharp edged corner; R2 - corner radius equal to 20 mm; R3 - corner radius equal to 38 mm. The FRP jackets were made either of CFRP or AFRP wraps and the geometry of the specimens included square and circular cross-sections. Comparison of gains of axial strength and ductility were presented and aspects of the variation of the lateral pressure and rupture of FRP jackets were examined. The improvement of axial load capacity gained, either from jackets of AFRP, or CFRP was almost equal for cylindrical columns. CFRP jacketed square column with sharp corner evidenced neither improvement of capacity, nor ductility. In the case of AFRP confinement there was improvement of load capacity, but no significant improvement on ductility.

El-Hacha and Mashrik [3] experimentally evaluated the effectiveness of steel fibre reinforced polymer (SFRP) sheets to confine small-scale plain concrete circular and square columns. Different parameters were investigated including: number of SFRP layers (1, 2, and 3), target concrete compressive strength (25, 30, and 35 MPa), cross-section of the columns (circular and square), and corner radius for square columns (3, 6, 10, and 25 mm). The experimental investigation was conducted in three phases. In Phase I, 36 circular specimens (150 mm diameter × 300 mm height) and in Phase II, 36 square specimens (150 mm side length × 300 mm height) were tested. In each phase, the specimens were divided into three groups according to concrete compressive strength. In each group, three specimens were tested without wrapping for comparison purposes, and three specimens for each number of layers. In Phase III, 12 SFRP wrapped (one layer) square specimens with a target concrete compressive strength of 25 MPa were tested to investigate the effect of varying the corner radii on the confined compressive strength. Figure 2.1 (Phase I) and (Phase II) shows comparison of average axial strength with respect to concrete compressive strengths and number of SFRP layers. The specimens were tested under monotonic concentric uni-axial compression load. Results showed that SFRP confinement improved the performance of both circular and square specimens in terms of axial strength and ductility; however, the improvement for square specimens was not as prominent as that for circular specimens. Rounding the corners of the square specimens improves the situation for square specimens and performance enhances with increasing corner radius. The confined concrete compressive strength was predicted using equations available in different codes and models and compared with experimental results.



(a) phase I



(b) phase II

Figure 2.1: Comparison of average axial capacity with respect to concrete compressive strengths and number of SFRP layers

Al-Salloum [4] presented the experimental and analytical results of the study conducted to investigate the influence of the radius of the cross-sectional corners (edges) on the strength of small scale square concrete column specimens confined with FRP composite laminates. The experimental part of the study was achieved by testing 20 specimens under uniaxial compression. Depending on the selected radius of the edges, the section varied from square to circular. Intermediate radii were about 1/6, 1/4, and 1/3 of the side dimension. The sharpest square specimens had a corner radius of 5 mm to make composite application easier and to avoid a premature rupture of the composite. The results showed that smoothening the edges of square cross-section plays a significant role in delaying the rupture of the FRP composite at these edges, and the efficiency of FRP confinement is directly related to the radius of the cross-section edges. A modified analytical model was presented to predict the strength of FRP-confined square as well as circular sections. Figure 2.2 clearly illustrates the

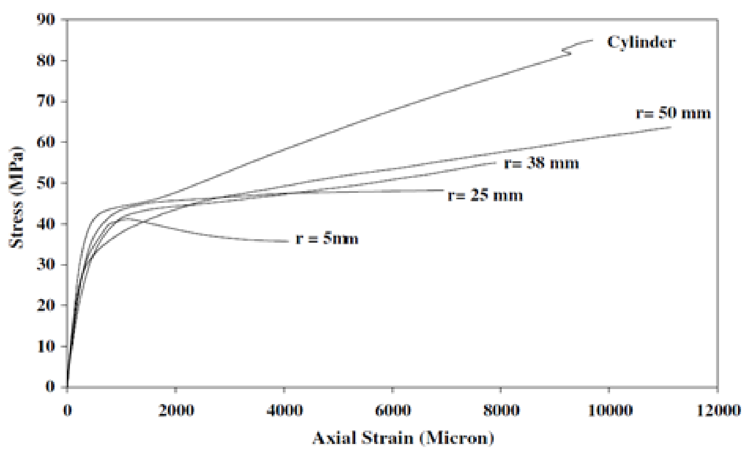


Figure 2.2: Effect of corner radius on confined square columns

effect of corner radii by comparing the stress-strain curves of square confined columns with corner radii (r) of 5, 25, 38, and 50 mm, with that of the confined cylinder. It can be seen that increasing the radius results in changing the behaviour of the confined square column to become gradually similar to that of a confined cylinder. This behaviour is illustrated in Figure 2.3.

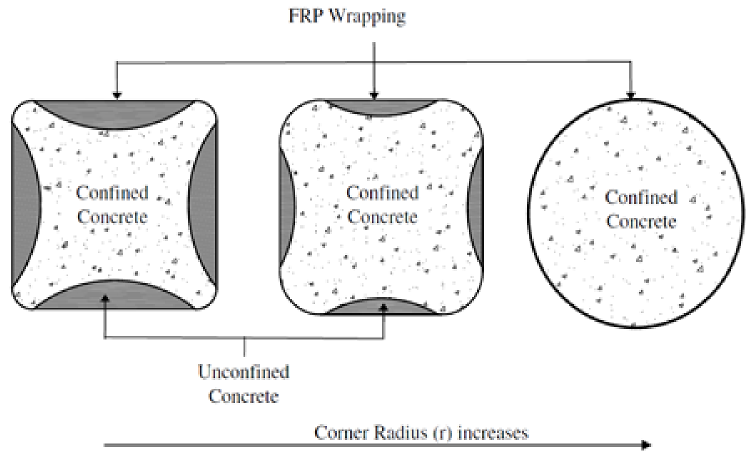


Figure 2.3: Effect of corner radius on confined concrete in square and cylindrical columns

Esfahani and Kianoush [5] presented the results of a study on the axial compressive strength of columns strengthened with FRP wrap. The experimental part of the study included testing 6 reinforced concrete columns in two series. The first series comprised three similar circular reinforced concrete columns strengthened with FRP wrap (Figure 2.4). The second series consisted of three similar square columns, two with sharp corners, and the other with rounded corners (Figure 2.5). Axial load and displacement of columns were recorded during tests using a displacement control test set up. Test results were compared with the values calculated using CSA (Canadian Standard Association) Code provisions. It was shown that the FRP wrap increases the strength and ductility of circular columns, significantly. According to the test results, the FRP wrap did not increase the strength of square columns with sharp corners. However, the square column with rounded corners exhibited a higher strength and ductility compared to those with sharp corners.

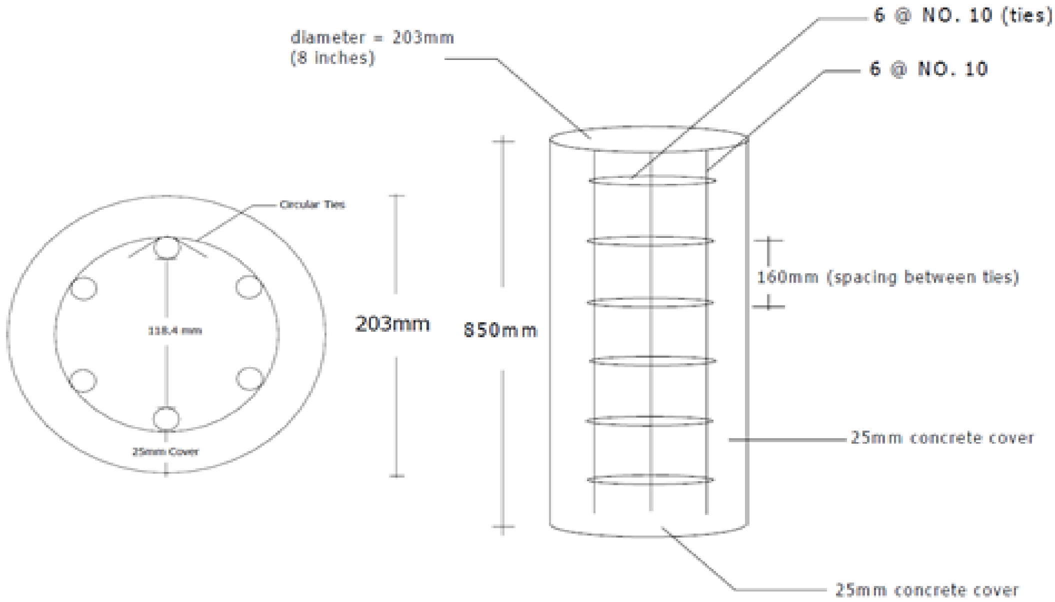


Figure 2.4: Circular column

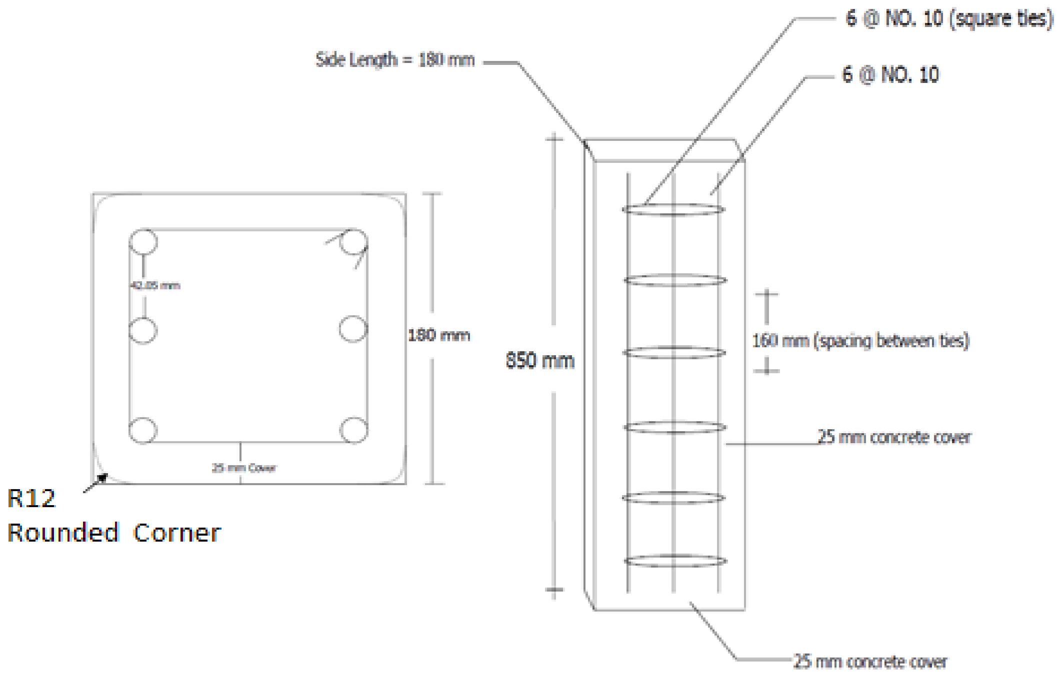


Figure 2.5: Square column

Wang and Hsu [6] proposed a design method and an experimental programme to evaluate the axial load strength of rectangular and square reinforced compression members confined with GFRP jackets and steel hoops. Three square and three rectangular columns were tested under axial compression up to failure. Figure 2.6 and Figure 2.7 shows dimension of columns, corner radius and reinforcement detail. The test results clearly showed the efficiency of the jackets in enhancing the ultimate strain and strength of the columns. The design method was calibrated using data from the tests. Closed-form equations are proposed for calculating the axial load strength of columns confined with FRP jackets.

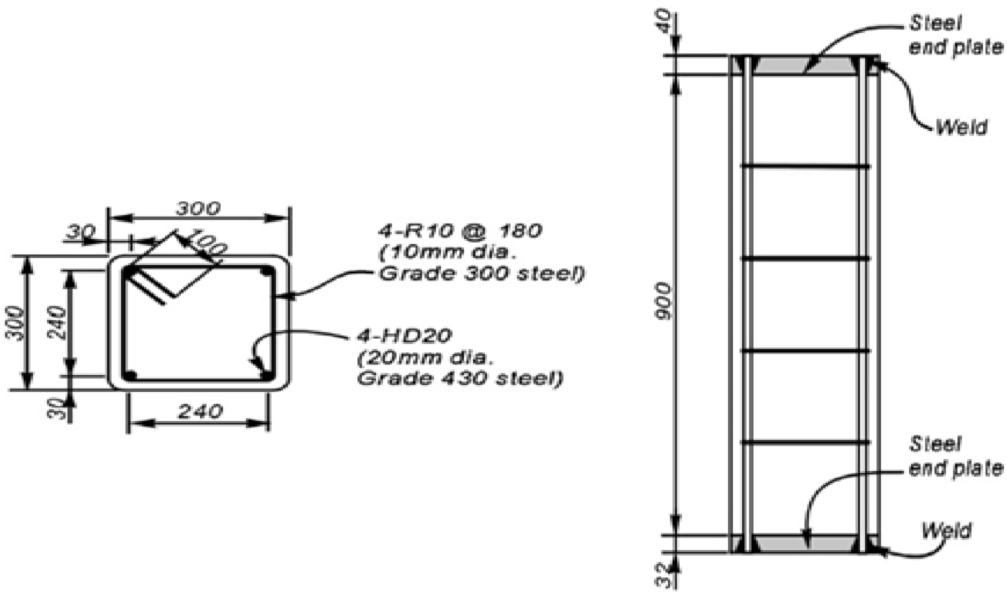


Figure 2.6: Reinforcing details of Square column

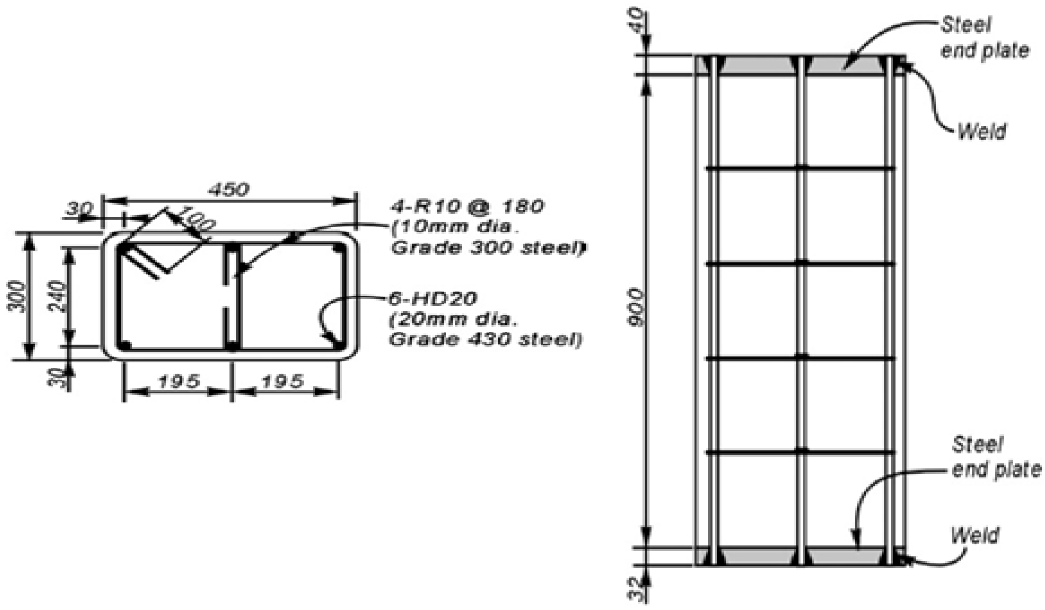


Figure 2.7: Reinforcing details of Rectangular column

Wang and Wu [7] examined how jacketing confines the concrete, and increases the strength and ductility of the jacketed columns. They suggested that a sharp corner (i.e., a zero corner radius) offers no confinement. The study was undertaken of compressive testing to investigate the effect of corner radius on the strength and ductility of FRP-confined concrete columns. A series of tests on 108 CFRP confined short concrete columns were conducted. The primary variables in the investigation were the corner radius, transverse jacket stiffness, and concrete grade. Figure 2.8 shows different location of strain gauges on the surface of specimen for sharp edges as well as for the specimen having different corner radii.

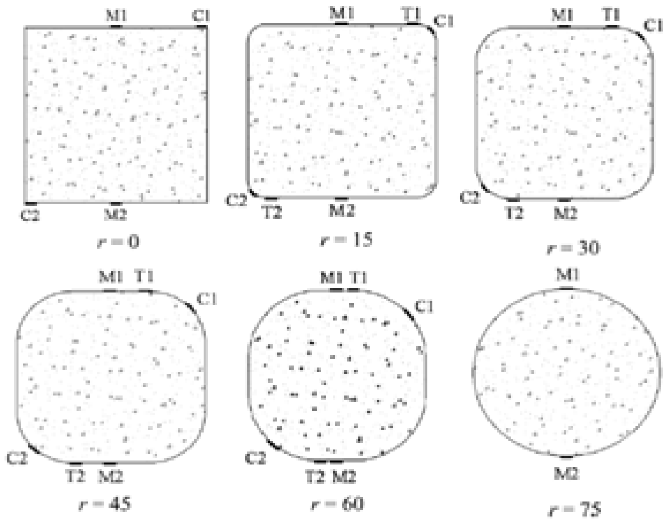


Figure 2.8: Strain gauge arrangements

Benzaid et al. [1] analysed experimental results in terms of load-carrying capacity and strains, obtained from tests on square prismatic concrete column, strengthened with external glass fibre composite. The parameters considered were the number of composite layers and the corner radius for a square shape. A total of twenty-one prisms of size 100 $\times$ 100 $\times$ 300 mm were tested under strain control rate of loading. From the test results it was suggested that a larger radius can expand the strong constraint zone and diminish the stress concentration. So the reduced confining pressure in a square section due to the concentration of stresses at the corners is solved by using a square section with corner radius. Figure 2.9 shows the plot of axial stress vs. axial strain for different corner radii as well as for the number of layers observed during the study.

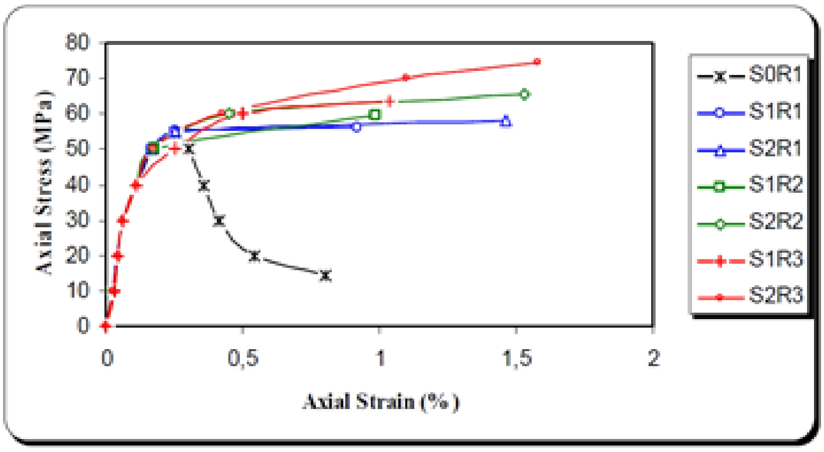


Figure 2.9: Stress-strain curves

Wu and Wei [8] conducted tests on rectangular columns strengthened with CFRP wrap. Three series of uniaxial compression tests were conducted on 45 specimens. The parameters considered were aspect ratio, defined as the depth (longer side) / width (shorter side) of the cross-section, and the number of CFRP layers. The behavior of the specimens in the axial and transverse directions was investigated. The test results clearly demonstrate that the strength gain in the confined concrete columns relative to the original unconfined columns, $f_{cc} = f_{co}$ decreases as the aspect ratio increases, until it becomes insignificant when the aspect ratio reaches 2. The test results were compared with the analytical and significant differences were found, indicating the need for further model development.

Toutanji et al. [9] focused on axially loaded, large-scale rectangular RC columns confined with FRP wrapping. Tests were conducted to obtain the stress-strain response and ultimate load for three field-size columns having different aspect ratios and/or corner radii. Effective transverse FRP failure strain and the effect of increasing confining action on the stress-strain behavior were examined. Existing strength models, the majority of which were developed for small-scale specimens, were applied to predict the structural response. Since some of them fail to adequately characterize the test data and others were complex and require significant calculation, a simple design-oriented model was developed. The new model was based on the confinement effectiveness coefficient, an aspect ratio coefficient, and a corner radius coefficient. It accurately predicts the axial ultimate strength of the large-scale columns at hand and, when applied to the small-scale columns studied by other investigators, produces reasonable results.

Luca at el. [**10**] presented a pilot research that includes laboratory testing of full-scale square and rectangular RC columns externally confined with glass and basalt-glass FRP laminates and subjected to pure axial load. Specimens that were representative of full-scale building columns were designed according to a American Concrete Institute (ACI) 318 code (i.e., prior to 1970) for gravity loads only. The study was conducted to investigate how the external confinement affects peak axial strength and deformation of a prismatic RC column. The results showed that the FRP confinement increases concrete axial strength, but it is more effective in enhancing concrete strain capacity. The discussions of the results included a comparison with the values obtained using existing constitutive models. Figure 2.10 shows plot of axial stress vs. axial deformation for control specimen and specimen with different wrapping material for square columns.

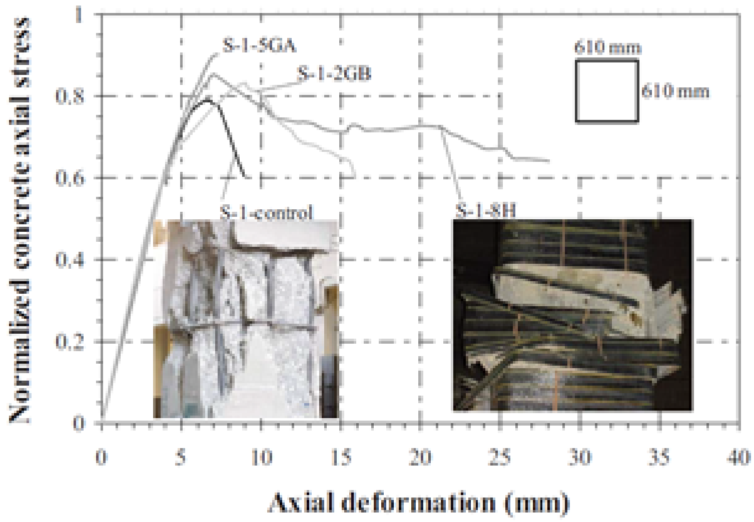


Figure 2.10: Axial stress vs. axial deformation

2.3 Analytical Work

El-Hacha and Mashrik [3] compared experimental results with predicted results using equations available in different codes and models for evaluated compressive strength of confined concrete. The maximum FRP-confined concrete compressive strength, f'_{cc} was predicted using the equations from the ACI Committee 440 (ACI 440.2R-08, 2008), CAN/CSA S6-06 Bridge Code, CAN/CSA S806-02 FRP Building Code, and the model by Spoelstra and Monti. In these predictions, the maximum FRP confined concrete compressive strength was based on the average measured unconfined concrete compressive strength f'_c in the corresponding test. Table 2.1 shows that the ACI model provides the most conservative estimation of the strength of SFRP confined cylinders.

Table 2.1: Comparison of predicted ultimate concrete compressive strength of SFRP confined cylinders

Specimen designation	Experimental f'_{cc} (MPa)	ACI 440.2R-08 [10]		S6-06 Bridge Code [20]		S806-02 FRP Building Code [19]	
		f'_{cc} MPa)	% diff.	f'_{cc} (MPa)	% diff.	f'_{cc} (MPa)	% diff.
C34.8W1	89.1	62.8	−29.4	67.1	−24.6	97.1	9.0
C34.8W2	142.3	90.9	−36.1	99.4	−30.1	149.6	5.1
C34.8W3	176.9	118.9	−32.8	131.7	−25.5	197.6	11.7
C41.1W1	99.8	69.1	−30.7	73.4	−26.4	102.4	2.6
C41.1W2	144.6	97.2	−32.8	105.7	−26.9	154.9	7.1
C41.1W3	183.5	125.2	−31.8	138.0	−24.8	202.9	10.6

The S6-06 Bridge Code uses a simple equation,

$$f'_{cc} = f'_c + 4.1 f_y \tag{2.1}$$

where,

f_y = yield strength

To determine the lateral confinement stress f_l (maximum confinement pressure due to FRP-jacket), S6-06 Bridge Code uses f_{fu} (design ultimate tensile strength of FRP) the ultimate tensile strength of FRP as the effective stress level in the FRP at failure, which was not a rational assumption, since due to non-uniform hoop strain distribution; FRP ultimate tensile strain and hence FRP ultimate tensile strength may not be reached at failure. For this reason, the ACI model included the strain efficiency factor; which given more conservative results compared to the S6-06 Bridge Code.

Wang and Hsu [6] presented nominal concentric compressive strength of a short concrete column,

$$P_n = P_{cn} + P_{sn} \tag{2.2}$$

Where,

P_{cn} = nominal compressive strength carried by the concrete,

P_{sn} = longitudinal reinforcing steel bars

For design purposes it was necessary to reduce the nominal concentric strength given in Eq. (2.3), to account for variations in the material properties, scatter in the design equation, bending of the columns, nature and consequences of failure and reduction in load carrying capacity under long-term loads. This reduction results in a dependable concentric strength, ϕP_n, for short column given by

$$\phi P_n = \phi_c P_{cn} + \phi_s P_{sn} \tag{2.3}$$

the ACI 318 Building Code requires for columns that the ultimate axial compressive load found from analysis shall not exceed ϕP_n calculated as,

$$\phi P_n = 0.80\phi(0.85 P_{cn} + P_{sn}) \tag{2.4}$$

For the axial compression members with transverse hoops, the strength reduction factor ϕ of 0.7 is adopted.Therefore, Eq. (2.4) becomes

$$\phi P_n = 0.476 P_{cn} + 0.56 P_{sn} \tag{2.5}$$

where,

$\phi_c = 0.476$ and $\phi_s = 0.56$

The predicted values resulting from the evaluation method correlate very well with the experimental results.

Esfahani and Kianoush [5] evaluated axial compressive strength of concrete columns without FRP wrap. According to CSA Standard A23.3-94, the axial strength of a reinforced concrete column is calculated by:

$$P_r = \phi_c \alpha 1 f'_c (A_g - A_{st}) + \phi_s f_y A_{st} \tag{2.6}$$

Where,

α 1=0.85-0.0015$f'_c \geq$ 0.67,

A_g = Gross area of section,

A_{st} = Total area of longitudinal reinforcement,

f_y = Specified yield strength of reinforcement,

ϕ_c and ϕ_s = Resistance factors for concrete and steel (=1 for laboratory conditions).

To calculate the value of confined concrete the following equation has been presented:

$$P_{rc} = \phi_c \alpha 1 f'_{cc} (A_g - A_{st}) + \phi_s f_y A_{st} \tag{2.7}$$

Where,

$f'_{cc} = f'_c \ (1 + \alpha_{pc} \ \omega_w)$

$\omega_w = f_{lfrp} \ / \ \phi_c \ f'_c$

$f_{lfrp} = 2N_{b\phi frp} \ E_{frp} \ \varepsilon_{frp} \ t_{frp}$(b+h) / (bh)

N_b = Number of layers of FRP

ε_{frp} = Resistance factor for the FRP (=1 for laboratory conditions)

f_{frpu} = Ultimate tensile strength of the FRP

t_{frp} = Thickness of the FRP

Proposed equation for FRP wrapped square columns can be used to predict the axial strength of square columns only if the corners of the columns are rounded appropriately.

Chapter 3

Analytical Study

3.1 General

Experimental study is conducted on Square RC column of size $125 \times 125 \times 1200$ mm. Analysis and design of Control RC column has been done according to IS 456:2000 [12] and ACI 318M-08 [13] provisions. Analysis and design of RC column strengthened using GFRP wrapping has been conducted using ACI-440.2R [14] provisions and is further included in this chapter.

3.2 Design of RC Column as per Indian Standard

Present investigation includes a short column subjected to axial compressive load. Therefore, the column is designed based on IS 456:2000 [12] provisions to check ultimate load carrying capacity of the member. Before evaluating the failure load of column, a check is made for its slenderness. Figure 3.1 shows cross section of the column with dimensions and direction of the application of axial load.

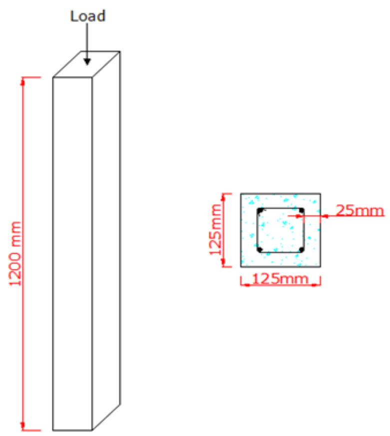


Figure 3.1: RC column with cross section

Parameters of assumed section of RC columns are as given in Table 3.1.

Table 3.1: Properties of control RC column

Column properties		
l	Length of column	1200 mm
b	Section width	125 mm
d	Section depth	125 mm
l_{ef}	Effective length of column	1200 mm
C_c	Clear cover	25 mm
f_{ck}	Characteristic cube compressive strength of concrete	20.57 N/mm^2 [Table 4.2]
f'_c	Specified compressive strength of concrete (0.8 $\times f_{cube}$)	16.46 N/mm^2 [3.3]
f_y	Characteristic strength of the compression reinforcement	415 N/mm^2

- **Check for Short Compression Members**

A compression member may be considered as a short column, when both the slenderness ratios l_{ex} / D and l_{ey} / b are less than 12.

For short axially loaded column,

$$Slenderness\ ratio = \frac{l_{ex}}{D}\ or\ \frac{l_{ey}}{b} < 12 \tag{3.1}$$

$$= 1200/125$$

$$= 9.6 < 12$$

Hence, this column is a short column.

- **Short Axially Loaded Members in Compression**

The member is designed by the following equation,

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc} \tag{3.2}$$

= 0.4 × 20.57 ×(15625 - 201.06)+(0.67 × 415 ×201.06)

= 182.81 kN

Where,

A_c = Area of concrete - A_{sc}

A_{sc} = Area of longitudinal reinforcement for columns

(Assuming 4 - 8 mm ϕ bars are used)

- **Calculation for Lateral Ties**

Pitch of transverse reinforcement shall not be more than the least of the following dimension:

i) The least lateral dimension of the compression members,

= 125mm

ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied,

= 16 × 8

= 128 mm

iii) 300 mm.

Diameter of transverse reinforcement shall be taken as per following recommendations:

i) The diameter of the lateral ties shall not be less than one fourth of the diameter of the largest longitudinal bar,

$= \frac{1}{4} \times 8$

= 2 mm

ii) In no case less than 6 mm.

Hence provide, 4 Nos. of 8mm ϕ bar as longitudinal reinforcement and 6mm ϕ bar 125mm c/c as transverse reinforcement. Details of test specimen are summarized in Figure 3.2.

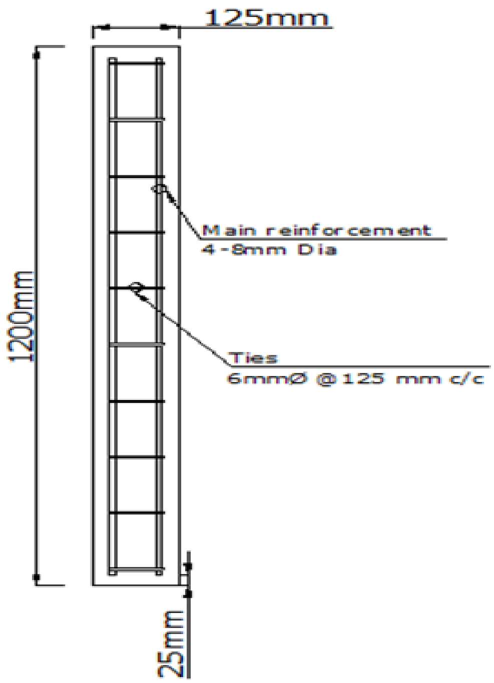


Figure 3.2: Reinforcement details of control RC column

3.3 Design RC Column as per ACI Provisions

IS 456:2000 [12] does not cover any provisions pertaining to design of FRP wrapped columns. The FRP wrapped columns are designed using provisions of ACI 440.2R - 08 [14]. However to maintain adequate correlation, the control columns are further designed based on provisions of ACI 318M - 08 [13]. Parameters of assumed section of RC columns are as given in Table 3.1.

For short axially loaded column,

$$P_n = 0.80[0.85 f'_c (A_g - A_{st}) + f_y A_{st}] \tag{3.3}$$

= 0.80 [0.85 ×(0.8 × 20.57) × (15625 - 201.06)] + (415 × 201.06)

= 239.34 kN

Where,

A_g = Gross area of concrete section

A_{st} = Total area of nonprestressed longitudinal reinforcement

(Assumed 4 - 8mm ϕ)

Note: f'_c= 0.8 $\times f_{cube}$

= 0.8 × 20.57 [Table 4.2]

= 16.46 N/mm^2

3.4 Design of RC Column Strengthened with GFRP Wrapping

It is desired to design an FRP wrapping for RC column of square section, in order to evaluate increase in load bearing capacity due to the wrapping. Before application of the wrapping, in order to avoid concentration of stresses at the corners, they have been rounded with various radii as shown in Figure 3.3. Following different corner radii have been considered:

- 0 mm Corner radius (Sharp edges)
- 15 mm Corner radius (Less than cover of 25 mm)
- 25 mm Corner radius (Equal to cover of 25 mm)
- 35mm Corner radius (More than cover of 25 mm)

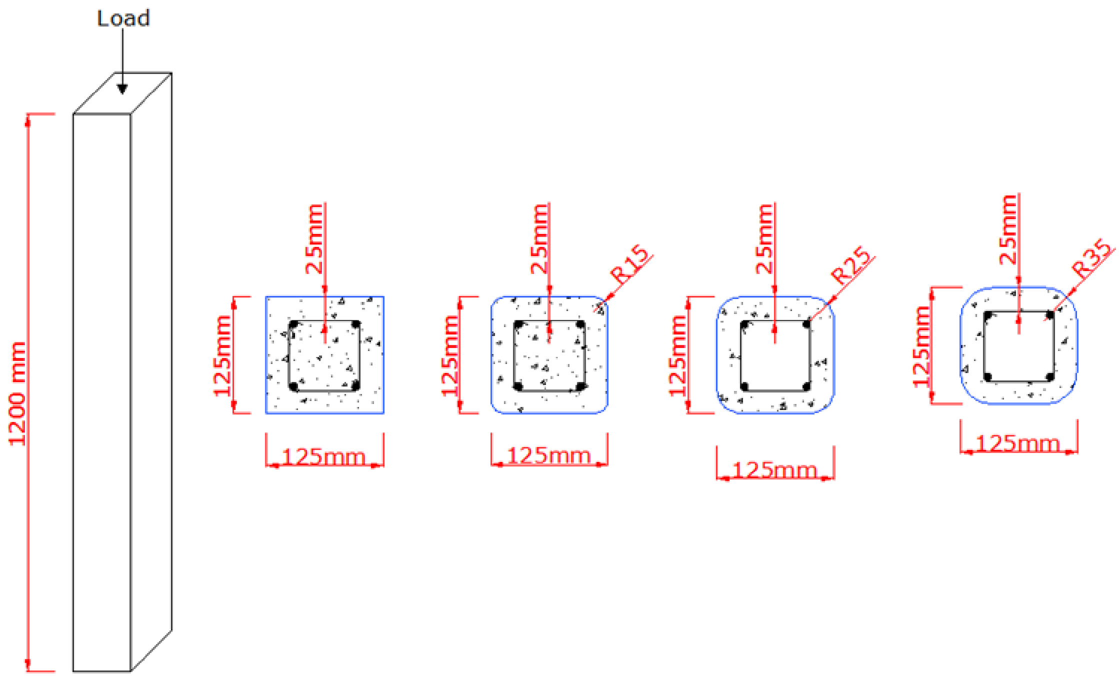


Figure 3.3: RC column with different corner radii

For axial column members with existing steel-tie reinforcement,

$$\phi P_n = 0.80\phi[0.85 f'_c(A_g - A_{st}) + f_y A_{st}] \tag{3.4}$$

$$= 0.80 \times 0.70 \, [\, 0.85 \, (0.8 \times 20.57) \times (15625 - 201.06) + 415 \times 201.06]$$

$= 167.55$ kN

Where,

ϕ = Strength reduction factor

= 0.70 (For members with tie reinforcement)

Properties of GFRP material used for wrapping the RC columns are given in Table 3.2.

Table 3.2: Properties of GFRP material

Thickness t_f (mm)	**Ultimate tensile strength f_{fu}* (MPa)**	**Modulus of Elasticity E_f (MPa)**	**Rupture strain ε_{fu}***
0.324	3400	74500	0.043

- **Column with Sharp Edges**

Sharp edges of columns are assumed to be having no corner radius. However, to avoid a premature rupture of the GFRP composite, 5mm corner radius has been provided and then wrapping is conducted using the GFRP sheet. Table 3.3 shows properties of RC column with sharp edges.

Table 3.3: RC Column Properties for Sharp edges

Column Properties		
l	Length of column	1200 mm
b	Short side dimension of compression member	125 mm
h	Long side cross-sectional dimension of rectangular compression member	125 mm
$\mathbf{r_c}$	Radius of edges of a prismatic cross section confined with FRP	5 mm
$\mathbf{A_g}$	Gross area of concrete section	15604 mm^2
$\mathbf{A_{st}}$	Total area of longitudinal reinforcement	201.06 mm^2
ρ_g	Ratio of area of longitudinal steel reinforcement to cross-sectional area of a compression member	1.29 %
f_c'	Specified compressive strength of concrete	16.46 N/mm^2
$\mathbf{f_y}$	Specified yield strength of nonprestressed steel reinforcement	415 N/mm^2
ϕP_n	Design axial strength	167.55 kN
ϕP_n **(req)**	Required % to achieve design axial strength	21%

Design procedure given in ACI 440.2R-08 [14] for GFRP wrapped RC column computes finally number of FRP layers required to achieve particular design strength. However, in the present case, the number of wrap is to be provided for RC columns are fixed. Thus, for ϕP_n of 167.55 kN and number of GFRP layer to be used for strengthening RC column is 1. Therefore, from back propagation technique,ϕP_n (req) has been calculated as 21 % for 0 mm radius single wrap RC column.

The calculations for RC column with 5mm corner radius and strengthened using 1 GFRP wrap are as follows:

Step 1: Computation of the FRP material properties

$$f_{fu} = C_E f_{fu} * \tag{3.5}$$

= 0.75 3400

= 2550 N/mm^2

$$\varepsilon_{fu} = C_E \varepsilon_{fu}* \tag{3.6}$$

= 0.75 x 0.043

= 0.032 mm/mm

where,

C_E = Environment reduction factor 0.75 for GFRP sheet

$f_{fu}*$ = Ultimate tensile strength

$\varepsilon_{fu}*$ = Rupture strain

Step 2: Determination of required maximum compressive strength of confined concrete f'_{cc}

$$f'_{cc} = \frac{1}{0.85(A_g - A_{st})}(\frac{\phi P_{nreq}}{0.80\phi} - f_y A_{st}) \tag{3.7}$$

$$= 23.38 \text{ N}/mm^2$$

where,

$\phi = 0.65$

ϕp_{nreq}= 202.54 N/mm^2

Step 3: Determination of maximum confining pressure due to the FRP jacket, f_l

$$f_l = \frac{f'_{cc} - f'_c}{3.3k_a} \tag{3.8}$$

$$= \frac{23.38-16.46}{3.3\times0.43}$$

$$= 4.90 \text{ N}/mm^2$$

where,

$$k_a = \frac{A_e}{A_c}(\frac{b}{h})^2 \tag{3.9}$$

$$= 0.43$$

$$\frac{A_e}{A_c} = \frac{1 - \frac{[(\frac{b}{h})(h-2r_c)^2+(\frac{h}{b})(b-2r_c)^2]}{3A_g} - \rho_g}{1-\rho_g} \tag{3.10}$$

$$= 0.43$$

Step 4: Determination of number of plies n

$$n = \frac{f_l\sqrt{b^2}+h^2}{\psi_f 2E_f t_f \varepsilon_{fe}} \tag{3.11}$$

$$= 1.01 \approx 1$$

where,

ψ_f = FRP strength reduction factor 0.95 for fully wrapped sections

E_f = Modulus of elasticity 74500 N/mm^2

t_f = Thickness of layer 0.324 mm

$$\varepsilon_{fe} = k_\varepsilon \varepsilon_{fu} \tag{3.12}$$

$$= 0.0177$$

k_ε = Efficiency factor 0.55

Similar, calculations are made for RC columns with 15 mm, 25 mm and 35 mm corner radii strengthened with 1 and 2 GFRP wrap, respectively. Results of all RC columns are summarized in Table 3.4.

Table 3.4: Various column parameters based on different code provisions

Notation	No. of Wraps	Corner Radius (mm)	Area (mm^2)	P_u as per IS 456 : 2000 (kN)	P_n as per ACI 318M - 08 (kN)	ϕP_n as per ACI 440.2R - 08 (kN)	ϕP_n (required) %	ϕP_n (kN)
S0R0	0	0	15625	182.81	239.34	-	-	-
S1R0	1	5	15604	182.63	239.12	167.55	21	202.54
S2R0	2	5	15604	182.63	239.12	167.55	49	249.40
S1R1	1	15	15432	181.23	237.20	166.04	32	219.17
S2R1	2	15	15432	181.23	237.20	166.04	71	283.92
S1R2	1	25	15089	178.41	233.36	163.35	41	230.32
S2R2	2	25	15089	178.41	233.36	163.35	89	308.73
S1R3	1	35	14573	174.17	227.61	159.32	48	235.80
S2R3	2	35	14573	174.17	227.61	159.32	102	321.84

Where,

Notation of Specimen:

S = Square column

0 = No wrapping

1 = Single layer of GFRP wrap

2 = Double layers of GFRP wrap

R0 = 5 mm corner radius

R1 = 15 mm corner radius

R2 = 25 mm corner radius

R3 = 35 mm corner radius

The values presented in Table 3.4 of various column parameters will be use full in comparing analytical results with experimental results and the same has been given in chapter.

Chapter 4

Experimental Work

4.1 General

This chapter deals with the casting and testing of RC column. Experimental work related to evaluation of compressive strength has been conducted on the column specimens. The columns are wrapped with GFRP composites to study the effect of varying corner radius and changing FRP layers in improvement of the compressive load carrying capacity of RC columns. RC columns have been tested under axial loading conditions.

4.2 Material Properties

4.2.1 Concrete

Castings of all columns are conducted by using M15 concrete grade mix. Mix design of M15 concrete has been made. Concrete mix proportion selected as Water : Cement : Sand : Coarse Aggregates, 0.60 : 1 : 3.25 : 5. Proportion of ingredients used for $1m^3$ concrete mix are shown Table 4.1. Table 4.2 shows average cube strength of 3 cubes after 28 day of curing period which was taken at the time of casting of specimens. Therefore, the average value of cube compressive strength of concrete is 20.57 N/mm^2

and also has been used in analytical computations in chapter 3 whenever required.

Table 4.1: Proportions of ingredients used for concrete mix ($1m^3$)

Ingredients	**Quantity**
Cement	270 kg/m^3
Sand	877.5 kg/m^3
10 mm aggregate	945 kg/m^3
20 mm aggregate	405 kg/m^3
Free water	162 kg/m^3

Table 4.2: Average Cube Strength

Batch No.	Date of Casting	Date of Testing	Average Dial Gauge Reading (kN)	Average Cube Strength (N/mm^2)
1	16/12/2011	13/01/2012	470	20.89
2	18/12/2011	15/01/2012	430	19.11
3	20/12/2011	17/01/2012	500	22.12
4	30/12/2011	27/01/2012	410	18.22
5	31/12/2011	28/01/2012	510	22.67
6	1/01/2012	29/01/2012	400	17.78
7	2/01/2012	30/01/2012	390	17.33
8	3/01/2012	31/01/2012	420	18.66
9	4/01/2012	1/02/2012	465	20.66
10	5/01/2012	2/02/2012	515	22.89
11	6/01/2012	3/02/2012	560	24.89
12	7/01/2012	4/02/2012	555	24.67
13	8/01/2012	05/02/2012	395	17.55
			Average value (N/mm^2)	20.57

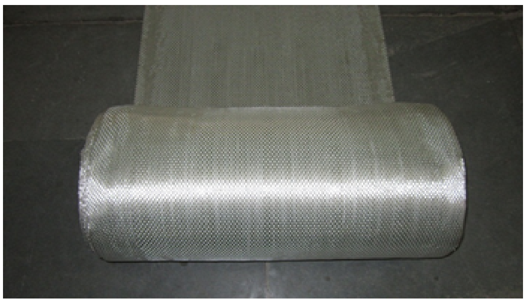
4.2.2 GFRP Sheet

The glass-fiber sheets used in present investigation were a unidirectional wrap. The properties of GFRP sheet are presented in Table 4.3. The resin system that is used to bond the glass fabrics over the columns is an epoxy resin made of two-parts, resin and hardener.

Table 4.3: GFRP Properties Supplied by Manufacturer

Fiber Weight (g/m^2)	Sheet Width (mm)	Fiber Thickness (mm)	Ultimate tensile strength (MPa)	Elastic modulus (MPa)	Ultimate elongation εfu (%)
900	500	0.324	3400	74500	4.3

Figure 4.1 (a) shows GFRP sheet which is available in roll form. This form is more flexible to carry from one place to the other place. Figure 4.1 (b) defines the direction of layers of fibers which is more in longitudinal direction as compared to the transverse direction.


(a) GFRP Sheet roll

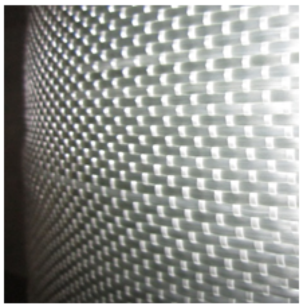

(b) Unidirectional GFRP sheet

Figure 4.1: GFRP sheet

4.3 Preparation of RC Column

A total of 27 RC square columns with a 125 mm × 125 mm cross-section and 1200 mm height with corner radius of 0 mm, 15 mm, 25 mm and 35 mm have been cast. Three columns were used as control specimens, and the remaining columns were wrapped with one and two layer of GFRP Sheet respectively. Concrete is prepared in the concrete mixture of $\frac{1}{2}$ (half) cement bag capacity. Casting of all the columns has been carried out in 13 different batches.

4.3.1 Steel Reinforcement Cages

Reinforcement cage for columns are prepared as shown in Figure 4.2 (a) and Figure 4.2 (b), respectively. 25 mm size PVC covers are used for providing the cover around all the sides of the columns.

(a) (b)

Figure 4.2: Reinforcement cage for columns with PVC cover

4.3.2 Formwork

Formwork plays very important role to maintain correct shape of the column and to achieve proper surface finishing. To avoid the problem of segregation and honeycombing in concrete, casting of the column is conducted by keeping the specimen in horizontal direction.

- **Formwork with Sharpe Edges for Square Column**

Formwork for the square columns has been prepared using 19 mm waterproof plywood sheets cut and assembled to provide 90° corners with a plywood formed bottom. The formwork is cut and assembled very carefully to ensure accurate vertical sides and 90° verticality for corners. Internal dimension of the formwork is 125 × 125 × 1200 mm. Figure 4.3 shows schematic view with dimensions of formwork. Figure 4.4 shows the competed formwork.

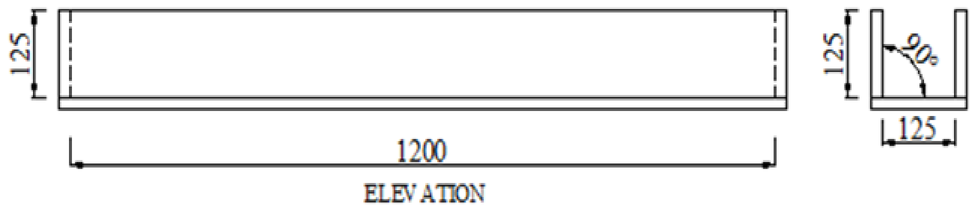


Figure 4.3: Schematic view of formwork with sharp edges

Figure 4.4: Completed formwork with sharp edges

- **Formwork with Corner Radius for Square Column**

In order to round off the corners of the square specimens, wooden patty inserts with the desired radius are fixed with the help of screw and cello tape at the corners of the boxes. Figure 4.5 shows different types of corner wooden patty which is fixed before the time of casting into the formwork to get the radius on the columns.

Figure 4.5: Different types of corner wooden patty

Figure 4.6 shows the various corner radii in schematic view and the position of corner patty in the formworks, respectively.

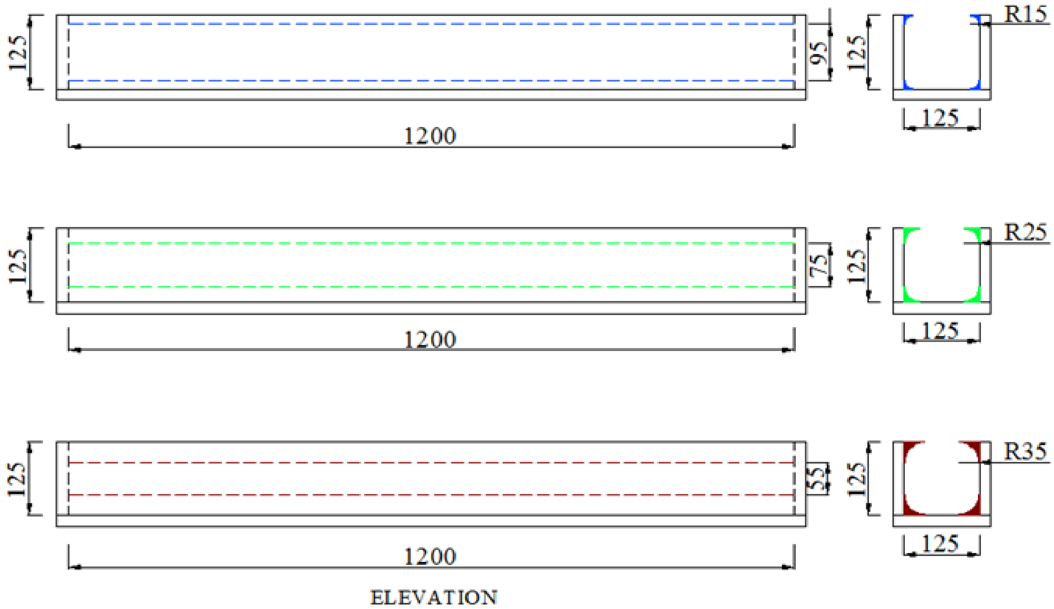
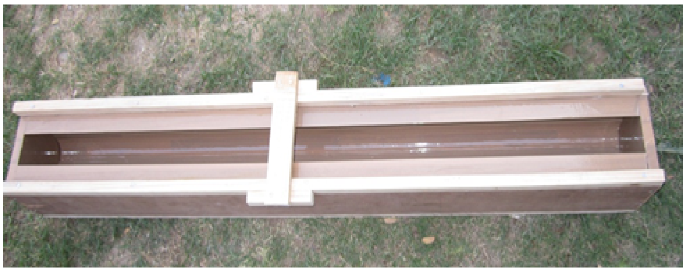
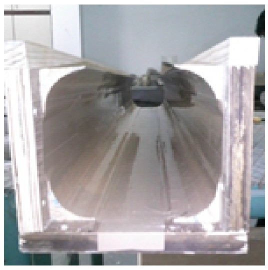


Figure 4.6: Schematic view of formwork for columns with corner radius 15mm, 25mm and 35mm

Figure 4.7 (a) and Figure 4.7 (b) show completed formwork for different corner radii RC columns. Wooden clamps are used at mid portion of the formwork in order to ensure that the assembled boxes would be able to resist the pressure of freshly cast concrete.



(a) Plan view



(b) c/s view

Figure 4.7: Completed formwork with corner radius patty

For getting smooth surface cello tape is applied on the inside surface of the formwork, which is also giving the protection to the formwork against the water. Figure 4.8 (a) and Figure 4.8 (b) show application of cello tape on the wooden patty and on the surface of plywood, respectively.

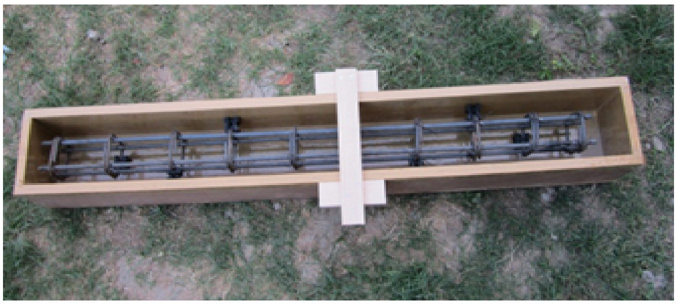
(a) Cello tape on wooden patty

(b) Cello tape on plywood

Figure 4.8: Application of cello tape on the surface of wooden patty and plywood

4.3.3 Casting of Specimens

Although the bottom surface of all the columns is covered by the formwork formed, the top surface has been finished very carefully using steel trowel to ensure the level surface. Figure 4.9 (a) and Figure 4.9 (b) show the formwork with reinforcement cages for sharp edges and for different corner radii of the columns.



(a) Formwork for sharp edges

(b) Formwork for different corner radii

Figure 4.9: Formwork with reinforcement cages for RC columns

The concrete mix is slowly poured into the forms to prevent the segregation, and the vibrator is used to vibrate the concrete carefully, to prevent formation of voids in concrete. Figure 4.10 shows the columns which are removed from the formwork after 24 hours of casting. Figure 4.11 shows columns being cured using gunny bags arranged on their surface. All columns are given uniform water curing for 28 days.

Figure 4.10: After 24 hour of casting

Figure 4.11: Curing period of specimens

4.4 Procedure of GFRP Wrapping

GFRP wrapping operation has been performed on concrete columns after 28 days of curing. The procedure of wrapping is discussed as follows:

4.4.1 Surface Preparation

Surface of the columns on three sides is quite good due to provision of cello tape on formwork however, the top surface is found uneven. Therefore, using Grinding process the top surface of the columns has been made smooth. The corner radii has already provided with help of wooden patty, Hence there is preparing the corners of the column is not required. Figure 4.12 shows the grinding operation on the column.

Figure 4.12: Grinding of column specimen

After the completion of the grinding, the columns are washed with water in order to remove loose particle from the concrete surface as shown in Figure 4.13.

Figure 4.13: Removing of dust by washing the specimen

4.4.2 Application of Primer

Before applying primer on the surface of concrete, care is taken that the columns are in saturanted surface dry condition. Primer is application the surface of the column where GFRP is to be added. Primer comprises of two solutions which are curing agent and base. Mixing of two part of base and one part of curing agent gives primer. Figure 4.14 (a) shows primer curing agent and Figure 4.14 (b) primer base. Figure 4.14 (c) shows mixing base and curing agent. Figure 4.14 (d) shows application of primer on surface of concrete with the help of brush. Figure 4.14 (e) shows the column surface after the application of primer.

(a) Primer curing agent

(b) Primer Base


(c) Mixing


(d) Applying one coat of primer


(e) After application of primer

Figure 4.14: Application of primer to column surface

4.4.3 Cutting of GFRP Sheet

The Square columns are of size 125 mm × 125 mm cross-section and of 1200 mm height. the GFRP sheet cutting is carried out. The perimeter of the section for single layer wrapping and 0 mm corner radius is 575 mm i.e. (125 × 4) + 75 = 575 mm. Overlap is kept 75 mm in column to ensure the development of tensile strength of full composite. Therefore same for other column 550 mm, 532 mm, 515 mm for corner radius 0 mm, 15 mm, 25 mm, 35 mm, are respectively. For double layer the perimeters are same as mention for the single layer but second layer is provided on first layer. Figure 4.15 (a) shows measuring of GFRP sheet for cutting. Figure 4.15 (b) and Figure 4.15 (c) shows cutting of GFRP sheet in transverse and longitudinal direction.

(a) Measuring of GFRP sheet

(b) Cutting of GFRP sheet in transvers direction

(c) Cutting of GFRP sheet in longitudinal direction

Figure 4.15: Cutting of GFRP sheet

4.4.4 Application of GFRP Sheet with Saturant

After drying of primer from the surface of the column, GFRP wrapping is done using saturant. Saturant consist of solutions one is curing agent and another is base. After mixing of one part of curing agent and two parts of base, the solution is applied on surface of concrete. The GFRP sheets are applied on the layer of saturat with the help of roller. After applying the GFRP sheet layer, one more coat of saturant is applied. For the double layer wrapping, GFRP sheet is applied on second coat of saturant. After the application of second layer of GFRP sheet surface is saturated by saturant. Special attention is given to the installers to eliminate any voids between the GFRP sheet and the concrete surfaces. Figure 4.16 (a) shows the container of Saturant curing agent and Saturant base. Figure 4.16 (b) shows mixing of both the solution cuing agent and base. Figure 4.16 (c) shows application of saturant with the help of brush. Figure 4.16 (d) shows application of GFRP sheet on the saturant layer. Figure 4.16 (e) shows completed GFRP wrapping on the column.

(a) Saturant curing agent and base

(b) Mixing

(c) Application of one coat of saturant

(d) Application of GFRP sheet

(e) After application of GFRP sheet and saturant

Figure 4.16: Application of GFRP sheet with saturant

4.5 Levelling of Column

Same formwork has been used for casting number of specimen during casting. As the base is not perpendicular to the height, chances of development of eccentricity are there during the application of load on the columns. To overcome this, the grinding is done on top and bottom face of the column. Figure 4.17 (a) shows out of plumb face of the column. Figure 4.17 (b) shows process of grinding for levelling the top and bottom surface of column. Figure 4.17 (c) shows plumb exactly matches with the face of the column.

(a) Before levelling of column (b) Grinding on the top and bottom (c) After grinding of base

Figure 4.17: Procedure of column levelling

4.6 Test Setup

The specimens are tested on loading frame under axial compressive loading. The axial load is applied through hydraulic jack of 2000 kN capacity and the capacity of the frame is 1000 kN. General arrangement of test setup is shown in Figure 4.18.

The columns are placed with hinged supports on either side. The load is applied from the bottom of column through hydraulic jack. Load is transferred from jack to supporting plate to column and finally on the loading frame through ground.

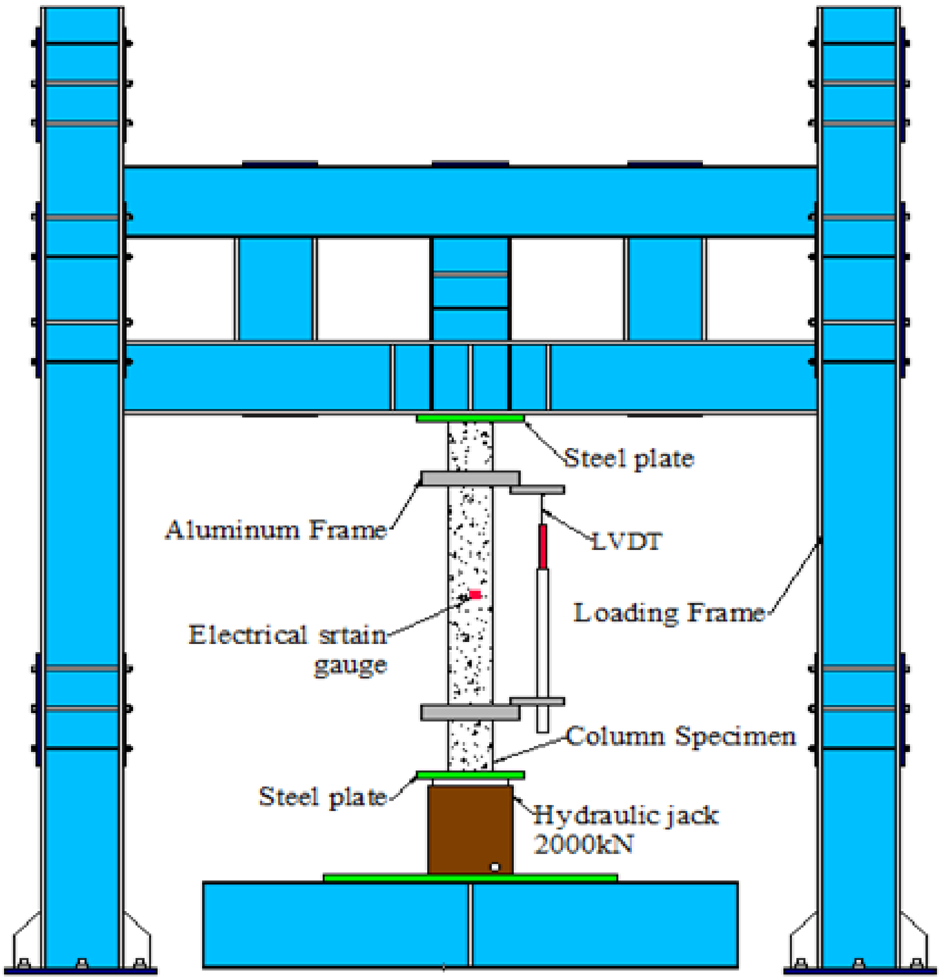


Figure 4.18: Schematic view of test setup for axial load

4.7 Instrumentation

Load, displacement and lateral strain for column specimens are measured using hydraulic jack, LVDT and electrical strain gauge, respectively. Various instruments used in experimental work are as follows:

4.7.1 Hydraulic Jack

Hydraulic jack of capacity of 2000 kN is used and is working based on Pascal's principle. Basically, the principle states that the pressure in a closed container is the same at all points. Pressure is described mathematically by a Force divided by Area. Therefore if there are two cylinders connected together, a small one & a large one, and a small force is applied to the small cylinder, this would result in a given pressure. Figure 4.19 shows the hydraulic jack which has been used for the application of axial load.

Figure 4.19: Hydraulic jack

4.7.2 LVDT (Linear Variable Differential Transducer)

The vertical displacement of the specimen was measured by linear variable differential Transducer (LVDT) with a travel of 50 mm which is mounted onto two aluminium frames that were fixed at the top and bottom of the specimen 800 mm apart, as shown in Figure 4.20.

(a) LVDT attached with column (b) Digital displacement Indicator

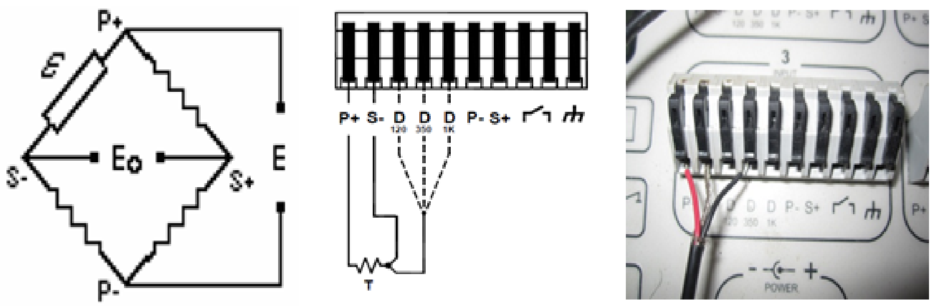
Figure 4.20: LVDT with aluminium setup

4.7.3 Electrical Strain Gauges

The Model P3 Strain Indicator and recorder is used for measuring lateral strain on the column. Data recorded at auto mode with rate of up to 1 reading per channel per second as well as manually and is transferred by USB to a computer. Figure 4.21 shows P3 strain indicator and recorder.

Figure 4.21: P3 strain indicator and recorder

Figure 4.22 (a) shows the circuit diagram for single active gauge and Figure 4.22 (b) shows the connections for making a three-wire quarter bridge connection. Bridge completion resistors of 120, 350 and 1000 ohms are built in for quarter-bridge operation. For bridge completion wire of 350 ohms is used for quarter bridge operation.



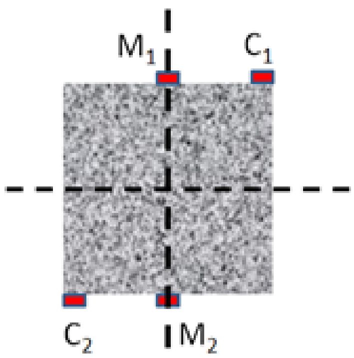
(a) Single active gauge in uniaxial tension or compression

(b) Quarter bridge connection

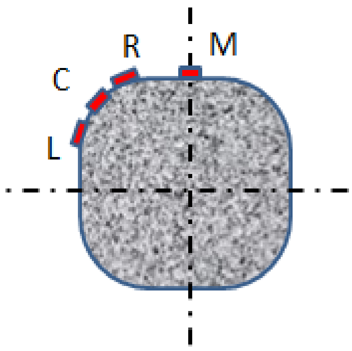
Figure 4.22: Circuit diagram and connection for Quarter bridge

- **Application of Electrical Strain Gauges**

All the columns are instrumented with strain gauges, glued either onto the concrete surface in the case of the control specimens or onto the outer layer of GFRP in case of the FRP-confined specimens. The strain gauges are mounted at multiple points at the mid-height of the columns to measure the strain at different locations. The gauge length of these electrical strain gauges is 5 mm. Figure 4.23 shows the locations of the transverse strain gauges, where M, C, L and R refer to positions on the side face, the centre of the corner, and the curvature changing point on the left and right-hand sides, respectively.



(a) Location of strain gauges on sharp edges



(b) Location of strain gauges on corner radius

(c) Strain gauges onto surface of concrete

(d) Strain gages onto surface of GFRP

Figure 4.23: Location of strain gauge

Chapter 5

Results and Discussion

5.1 General

This chapter deals with reporting of test results like: Axial compressive load, displacement and strain for control and wrapped column with various corner radii. Load is increased on the column at specific intervals and corresponding to every load displacement and lateral strains are measured for the columns. Comparison of Ultimate failure load, maximum displacement, lateral strain and axial strain evaluated at different positions for both categories of columns is presented in tabular as well as in graphical form. These parameters are very essential to understand the behaviour of control and GFRP wrapped columns. Different parameters discussed in this chapter for RC columns are as follows:

- Ultimate failure load
- Load vs. displacement
- Axial stress vs. strain
- Corner radius effect
- Failure modes

- Comparison of experimental and analytical results

5.2 Notations for Columns

Following notations have been used during reporting of all results in this chapter:

S0R0 = Control column

S1R0 = One layer of GFRP sheet for column having 5 mm corner radius

S2R0 = Two layers of GFRP sheet for column having 5 mm corner radius

S1R1 = One layer of GFRP sheet for column having 15 mm corner radius

S2R1 = Two layers of GFRP sheet for column having 15 mm corner radius

S1R2 = One layer of GFRP sheet for column having 25 mm corner radius

S2R2 = Two layers of GFRP sheet for column having 25 mm corner radius

S1R3 = One layer of GFRP sheet for column having 35 mm corner radius

S2R3 = Two layers of GFRP sheet for column having 35 mm corner radius

5.3 Ultimate Failure Load

Interval for load increment is taken as 10 kN. This interval is kept constant up to the complete failure of the column specimen. Experimental average failure load for all RC columns are given in Table 5.1.

Table 5.1: Ultimate failure load for RC columns

Sr. No.	Code	Ultimate Failure Load (kN)	Average ultimate failure load (kN)
1	S0R0	310	303.33
2		310	
3		290	
4	S1R0	460	446.67
5		440	
6		440	
7	S2R0	590	596.67
8		570	
9		630	
10	S1R1	490	486.67
11		460	
12		510	
13	S2R1	470	700.00
14		730	
15		670	
16	S1R2	630	573.33
17		540	
18		550	
19	S2R2	800	756.67
20		730	
21		740	
22	S1R3	560	553.33
23		600	
24		500	
25	S2R3	690	666.67
26		680	
27		630	

Average values are considered for finding percentage variations. Percentage increment in failure load for all columns is presented in Table 5.2. Higher load carrying capacity has been observed for all wrapped columns as compared to that of unwrapped columns. Percentage increment in ultimate failure load is ranging from 8.10 % to 149.45 % for all wrapped columns as compared to that of unwrapped columns. As compared to S0R0 column increment in ultimate failure load observed of 47.25 %, 96.70 %, 60.44 %, 130.77 %, 89.01 %, 149.45 %, 82.42 % and 119.78 % for columns S1R0, S2R0, S1R1, S2R1, S1R2, S2R2, S1R3 and S2R3, respectively. Similar type of comparison can also be evaluated for all columns using Table 5.2.

Table 5.2: Percentage increment in ultimate failure load

Specimen	S0R0	S1R0	S2R0	S1R1	S2R1	S1R2	S2R2	S1R3	S2R3
S0R0	-	47.25	96.70	60.44	130.77	89.01	149.45	82.42	119.78
S1R0		-	33.58	8.96	56.72	28.36	69.40	23.88	49.25
S2R0			-	-18.44	17.32	-3.91	26.82	-7.26	11.73
S1R1				-	43.84	17.81	55.48	13.70	36.99
S2R1					-	-18.10	8.10	-20.95	-4.76
S1R2						-	31.98	-3.49	16.28
S2R2							-	-26.87	-11.89
S1R3								-	20.48
S2R3									-

Comparison of ultimate failure load keeping corner radius constant

Figure 5.1 to Figure 5.4 show comparison of ultimate failure load for column specimens keeping corner radius constant. Figure 5.1 shows comparison between S0R0, S1R0 and S2R0, respectively. Here the corner keeping R0 has been kept constant and the numbers of FRP layers are varied as to single wrap and double wrap. Increase in ultimate load carrying capacity of 47.25 % and 96.70 % has been observed for columns S1R0 and S2R0 as compared to that for column S0R0, respectively.

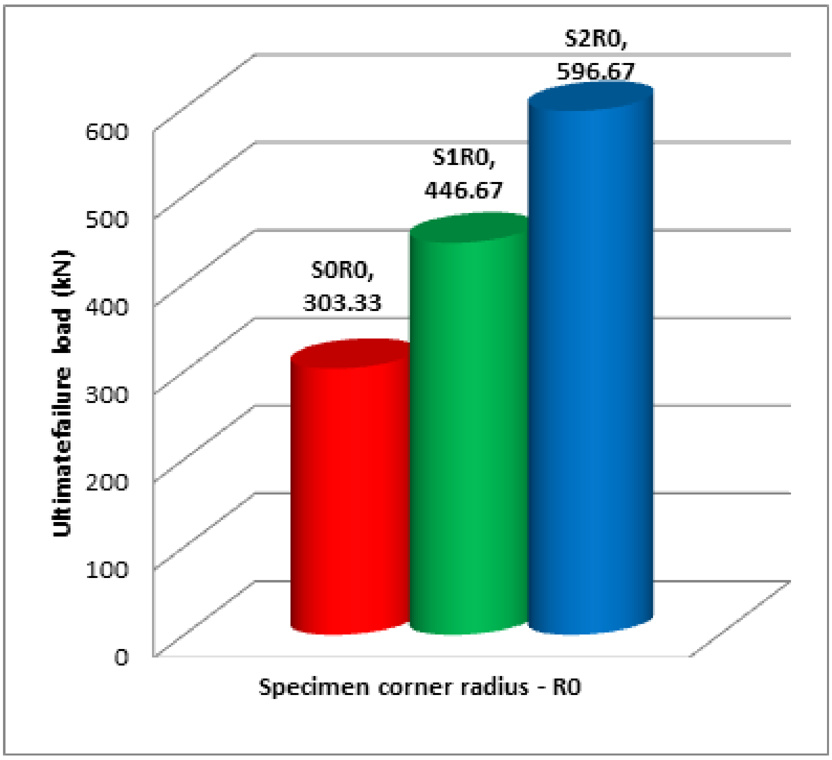


Figure 5.1: R0 columns with corner radius

Figure 5.2 shows the comparison between S1R1 and S2R1 keeping corner radius R1 constant. Comparing S1R1 to S2R1 the value of ultimate load carrying capacity increased with 43.84 % for specimen S2R1.

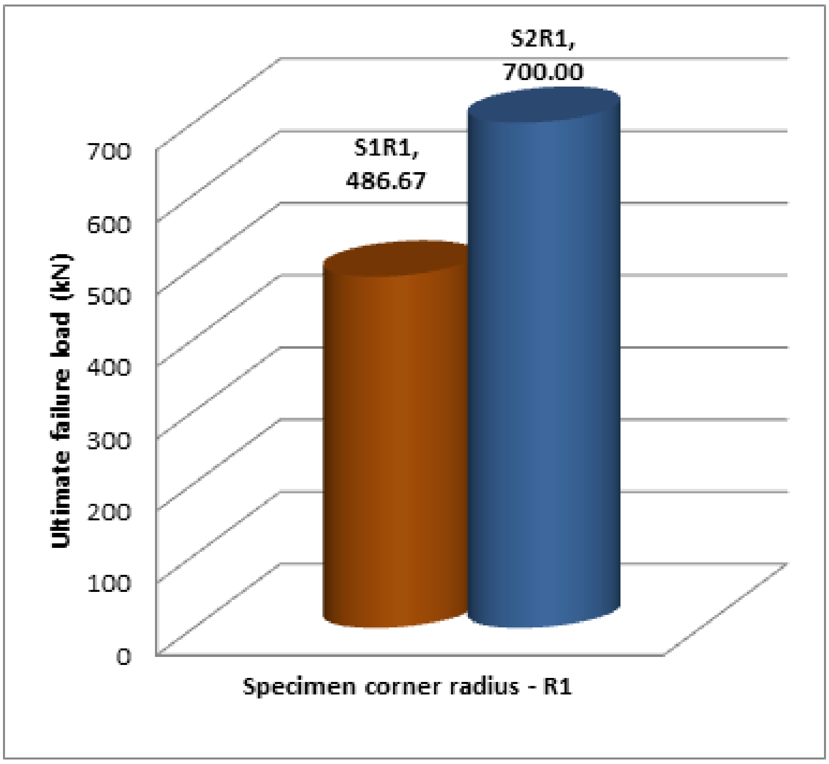


Figure 5.2: R1 columns with corner radius

Figure 5.3 shows the comparison between S1R2 and S2R2 keeping corner radius R2 as a constant, value of ultimate load carrying capacity of column increase by 31.98 % for specimen S2R2 as compare with S1R2. Figure 5.4 shows comparison between S1R3 and S2R3 keeping corner radius R3 as a constant, value of ultimate load carrying capacity of column increased by 20.48 % for specimen S2R3 as compare with S1R3.

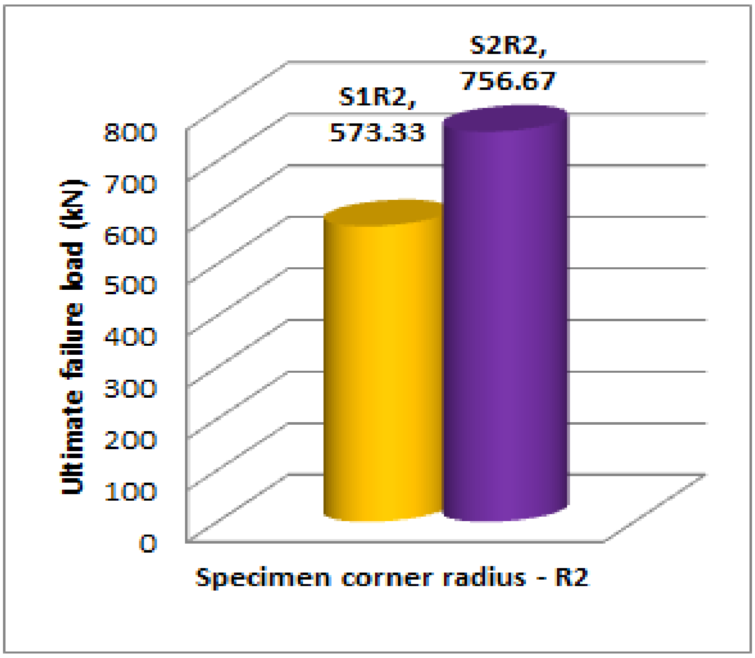


Figure 5.3: R2 columns with corner radius

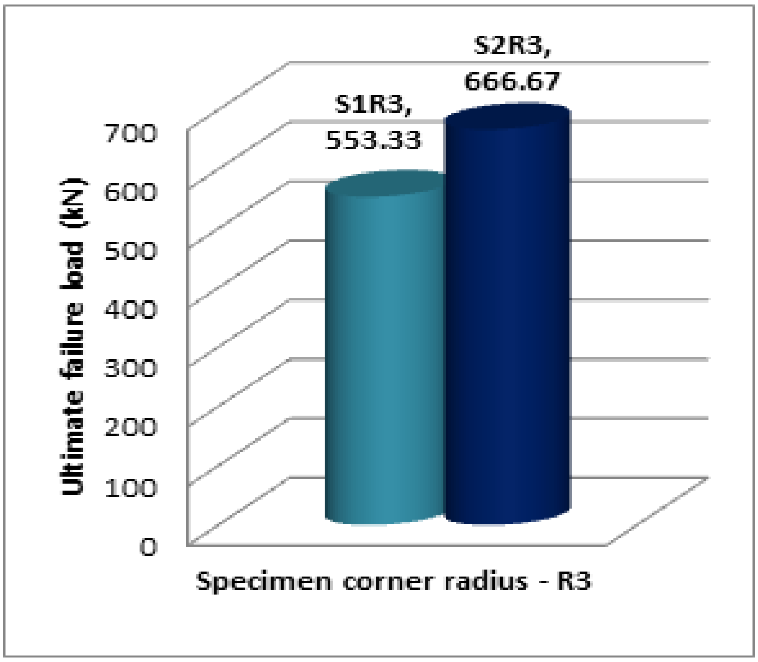


Figure 5.4: R3 columns with corner radius

Comparison of ultimate failure load keeping number of layers constant

Figure 5.5 shows that as the numbers of FRP layer increase the load carrying capacity of column is also increased. Comparing as single layer wrapped specimens S1R0, S1R1, S1R2 and S1R3 the ultimate load carrying capacity increase as shown in Figure 5.5. Percentage variation as compare with S1R0 to S1R1, S1R1 to S1R2 and S1R2 to S1R3 are 8.96 %, 17.81 % and - 3.49 % respectively.

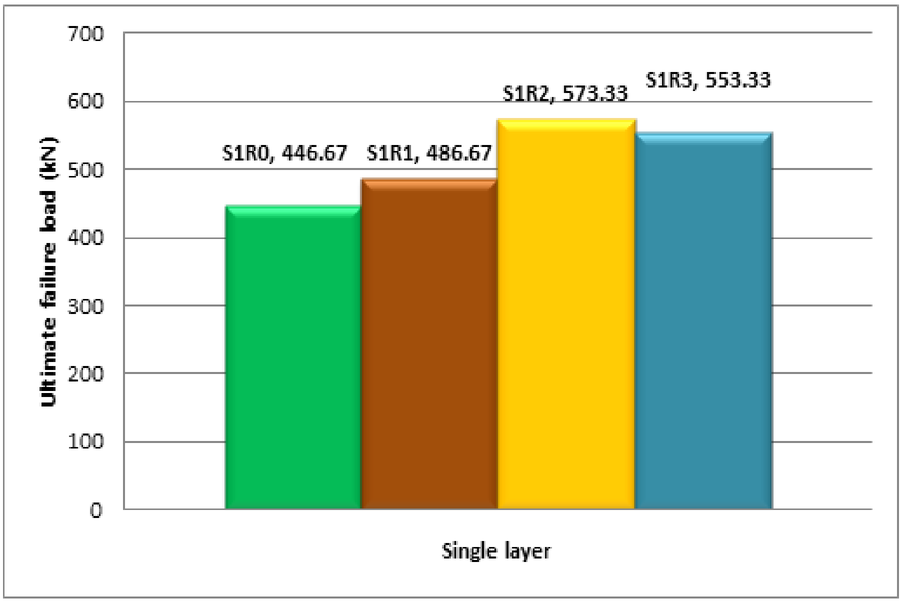


Figure 5.5: Column wrapped with single GFRP layer

For the double layers wrapped column the ultimate load carrying capacity increased as same manner in single layer wrapped column. Comparing as double layer wrapped specimens S2R0, S2R1, S2R2 and S2R3 the ultimate load carrying capacity increase as shown in Figure 5.6. Percentage variation as compare with S2R0 to S2R1, S2R1 to S2R2 and S2R2 to S2R3 are 17.32 %, 8.10 % and - 11.89 % respectively.

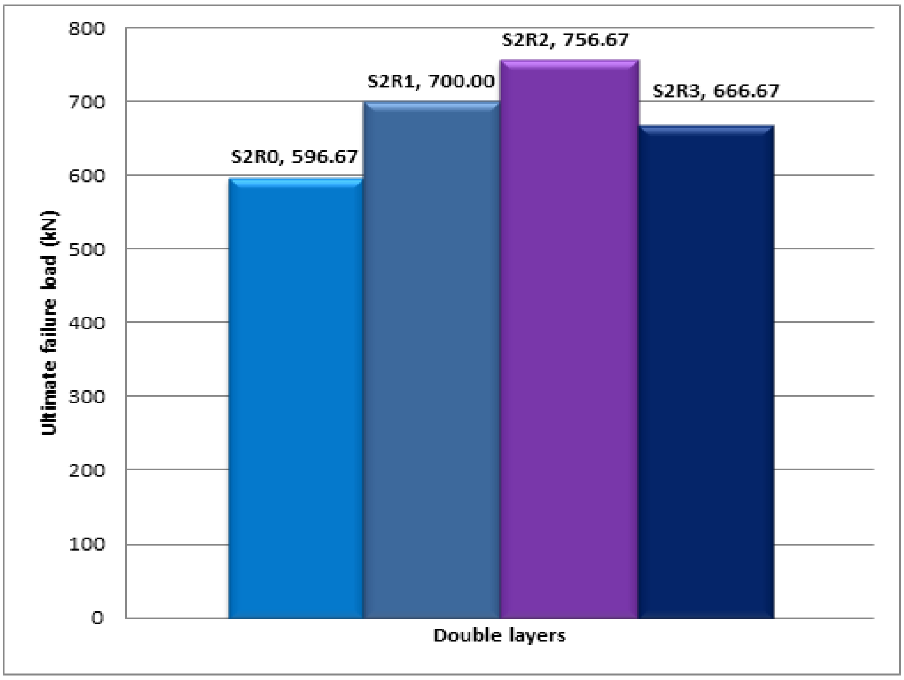


Figure 5.6: Column wrapped with double GFRP layers

From specimen S0R0 to S2R3 the specimen radii as well as number of layers are increase, therefore in the case of radius variation as the radius increases the confinement increases which is provided by GFRP layer to the control column as shown in Figure 2.3. When the FRP layers provided in more numbers as the first layer gets confinement, the second layer provided further confinement to it. Therefore the strength of RC column is obtained in increasing manner.

Ideally for all columns ultimate failure load should increase with increase in corner radius from 0 mm, 15 mm, 25 mm and 35 mm, but in case columns having corner radius 35 mm shows less ultimate failure load than 25 mm corner radius column. For specimen having corner radius 35 mm, the specimen clear cover reduced from 25 mm to 20.51 mm at the corner as shown in Figure 5.7. Therefore the ultimate failure of the specimen S1R3 and S2R3 are failing earlier than the column S1R2 and S2R2. Due to premature failure of the specimen is also a reason for lower value of ultimate failure load for 35 mm corner radius specimen.

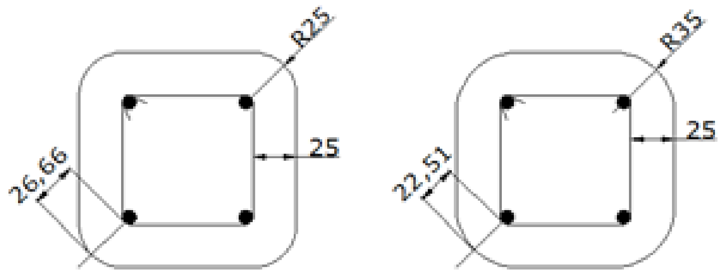


Figure 5.7: Variation in clear cover with different corner radius

5.4 Load vs. Displacement

Displacement is measured along the length of the column. The gauge length of column for measuring the displacement is kept 800 mm. To set the LVDT for measuring the displacement of column, aluminium frame setup is developed. Displacement of all the columns is measured at an interval of every 10 kN load till the application of ultimate load.

Comparison of ultimate failure load vs. displacement keeping corner radius constant

Table 5.3 shows average displacement at average ultimate failure load for specimen S0R0. Displacement readings for all the columns are individually shown in tabular form in Appendix A.

Table 5.3: Average displacement of specimen S0R0

Specimen S0R0			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	150	0.31
10	0.01	160	0.34
20	0.04	170	0.35
30	0.06	180	0.37
40	0.07	190	0.39
50	0.09	200	0.40
60	0.11	210	0.42
70	0.14	220	0.45
80	0.16	230	0.48
90	0.19	240	0.50
100	0.21	250	0.52
110	0.23	260	0.54
120	0.26	270	0.58
130	0.28	280	0.61
140	0.29	290	0.63

Table 5.4 shows average displacement at average ultimate failure load for specimen S1R0.

Table 5.4: Average displacement of specimen S1R0

Specimen S1R0			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	250	0.68
10	0.06	260	0.72
20	0.10	270	0.75
30	0.14	280	0.79
40	0.17	290	0.83
50	0.18	300	0.87
60	0.21	310	0.92
70	0.23	320	0.97
80	0.25	330	1.02
90	0.27	340	1.08
100	0.29	350	1.13
110	0.31	360	1.22
120	0.33	370	1.31
130	0.35	380	1.40
140	0.37	390	1.53
150	0.40	400	1.72
160	0.42	403	2.01
170	0.45	407	2.72
180	0.48	403	2.87
190	0.51	400	3.21
200	0.54	403	3.26
210	0.57	413	4.01
220	0.60	423	4.71
230	0.62	430	5.91
240	0.65		

Table 5.5 shows average displacement at average ultimate failure load for specimen S2R0.

Table 5.5: Average displacement of specimen S2R0

Specimen S2R0							
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	250	0.72	500	2.50	577	10.01
10	0.02	260	0.76	510	2.66		
20	0.04	270	0.80	520	2.95		
30	0.07	280	0.85	530	3.24		
40	0.09	290	0.90	540	3.53		
50	0.11	300	0.93	550	3.90		
60	0.15	310	0.97	553	4.42		
70	0.18	320	1.00	557	4.86		
80	0.20	330	1.06	553	5.06		
90	0.22	340	1.10	557	5.00		
100	0.25	350	1.16	553	5.60		
110	0.28	360	1.21	563	5.75		
120	0.31	370	1.27	573	6.06		
130	0.33	380	1.32	577	6.57		
140	0.36	390	1.37	580	7.26		
150	0.39	400	1.44	570	7.45		
160	0.42	410	1.51	567	7.61		
170	0.44	420	1.58	570	7.76		
180	0.48	430	1.68	580	7.98		
190	0.50	440	1.75	583	8.57		
200	0.54	450	1.82	580	8.91		
210	0.58	460	1.94	583	9.25		
220	0.62	470	2.03	580	9.39		
230	0.65	480	2.16	583	9.63		
240	0.68	490	2.35	580	9.87		

Figure 5.8 shows the average load vs. average displacement plot for specimen S0R0, S1R0 and S2R0. The displacement value for specimens S1R0 and S2R0 are more compared to specimen S0R0. For S0R0, S1R0 and S2R0 the value of average displacement are 0.63 mm, 5.91 mm and 10.01 mm and average ultimate load corresponding to displacement are 290 kN, 430 kN and 577 kN, respectively. The behaviour of all three specimens are similar up to 200 kN load.

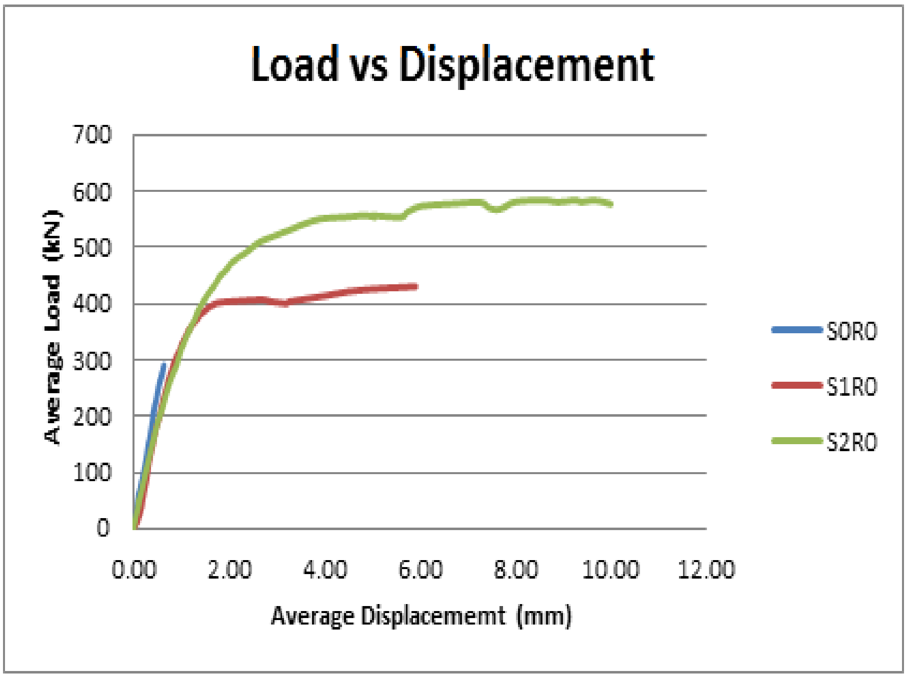


Figure 5.8: R0 corner radius specimens with single and double layers

Table 5.6 shows average displacement at average ultimate failure load for specimen S1R1.

Table 5.6: Average displacement of specimen S1R1

Specimen S1R1					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	250	1.05	467	5.82
10	0.02	260	1.10	463	6.18
20	0.05	270	1.17		
30	0.10	280	1.25		
40	0.14	290	1.32		
50	0.17	300	1.39		
60	0.20	310	1.52		
70	0.26	320	1.68		
80	0.32	330	1.80		
90	0.37	340	1.90		
100	0.44	350	2.04		
110	0.47	360	2.21		
120	0.51	370	2.37		
130	0.54	380	2.53		
140	0.57	390	2.68		
150	0.59	400	2.86		
160	0.63	410	3.05		
170	0.68	420	3.33		
180	0.71	430	3.63		
190	0.75	440	3.84		
200	0.79	450	4.21		
210	0.84	453	4.74		
220	0.89	450	4.85		
230	0.94	453	5.05		
240	0.99	457	5.42		

Table 5.7 shows average displacement at average ultimate failure load for specimen S2R1.

Table 5.7: Average displacement of specimen S2R1

Specimen S2R1							
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	250	0.72	500	2.88	650	10.09
10	0.04	260	0.76	510	3.09	660	10.25
20	0.09	270	0.80	520	3.28	670	10.43
30	0.13	280	0.85	530	3.52	670	10.74
40	0.15	290	0.89	540	3.80	670	11.11
50	0.17	300	0.93	550	3.98		
60	0.20	310	0.98	560	4.24		
70	0.22	320	1.03	570	4.63		
80	0.24	330	1.09	580	4.99		
90	0.27	340	1.13	590	5.22		
100	0.30	350	1.19	600	5.65		
110	0.32	360	1.26	610	6.39		
120	0.35	370	1.34	620	7.01		
130	0.37	380	1.39	610	7.14		
140	0.40	390	1.47	600	7.21		
150	0.42	400	1.56	610	7.41		
160	0.45	410	1.62	620	7.55		
170	0.48	420	1.74	630	7.74		
180	0.50	430	1.84	640	7.99		
190	0.53	440	1.93	640	8.27		
200	0.56	450	2.03	640	8.90		
210	0.59	460	2.23	640	9.18		
220	0.63	470	2.37	640	9.50		
230	0.66	480	2.51	650	9.71		
240	0.69	490	2.64	650	9.99		

Average load vs. average displacement plot for Specimen S1R1 and S2R1 are shown in Figure 5.9. For S1R1 and S2R1 the values of average displacement are 6.18 mm and 11.11 mm and average ultimate load corresponding to displacement are 463 kN and 670 kN, respectively. The average displacement at ultimate load of specimen S2R1 are increased by 80 % compared to specimen S1R1.

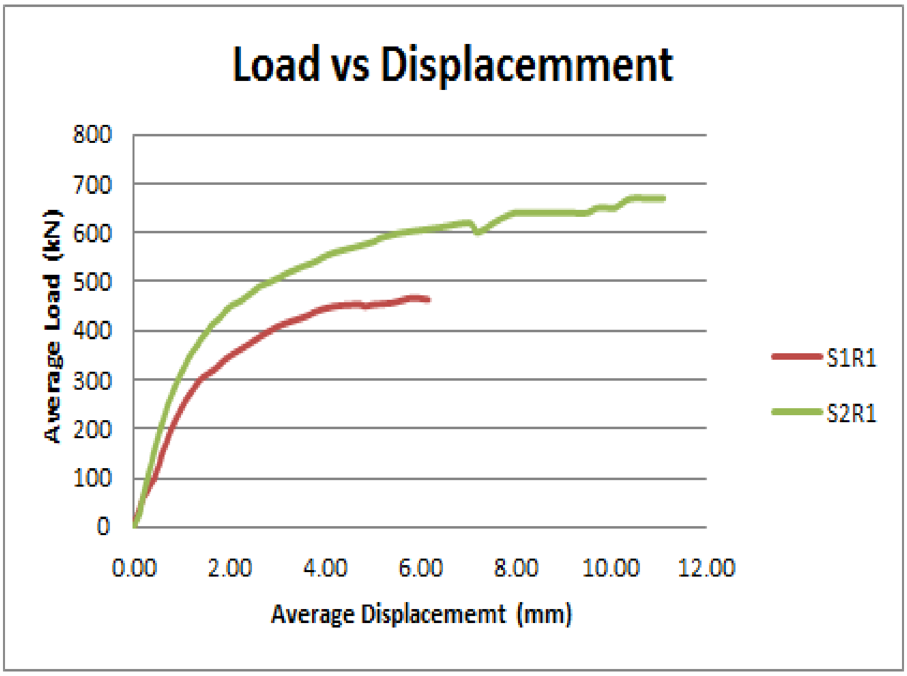


Figure 5.9: R1 corner radius specimen with single layer and double layers

Table 5.8 shows average displacement at average ultimate failure load for specimen S1R2.

Table 5.8: Average displacement of specimen S1R2

Specimen S1R2					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	190	0.76	380	2.50
10	0.03	200	0.83	390	2.72
20	0.05	210	0.89	400	2.89
30	0.07	220	0.94	410	3.15
40	0.09	230	1.01	420	3.39
50	0.10	240	1.08	430	3.61
60	0.13	250	1.15	440	4.05
70	0.16	260	1.23	450	4.39
80	0.19	270	1.29	460	4.64
90	0.22	280	1.39	470	5.03
100	0.27	290	1.47	480	5.30
110	0.31	300	1.55	490	5.68
120	0.35	310	1.66	500	6.13
130	0.40	320	1.75	510	6.69
140	0.46	330	1.84	520	7.12
150	0.51	340	1.95	530	7.41
160	0.57	350	2.06	540	7.81
170	0.62	360	2.18		
180	0.68	370	2.34		

Table 5.9 shows average displacement at average ultimate failure load for specimen S2R2.

Table 5.9: Average displacement of specimen S2R2

Specimen S2R2							
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	200	0.72	400	2.25	600	6.64
10	0.03	210	0.77	410	2.37	610	6.95
20	0.07	220	0.82	420	2.49	620	7.18
30	0.12	230	0.87	430	2.63	630	7.49
40	0.15	240	0.92	440	2.75	640	7.83
50	0.18	250	0.97	450	2.90	650	8.38
60	0.21	260	1.05	460	3.03	660	8.82
70	0.24	270	1.12	470	3.17	670	9.36
80	0.26	280	1.19	480	3.33	680	9.55
90	0.29	290	1.26	490	3.52	690	9.79
100	0.32	300	1.34	500	3.75	700	10.41
110	0.35	310	1.42	510	3.98	697	10.92
120	0.38	320	1.50	520	4.22	687	11.04
130	0.42	330	1.58	530	4.50	690	11.22
140	0.45	340	1.64	540	4.71	700	11.44
150	0.49	350	1.72	550	5.00	710	11.65
160	0.53	360	1.88	560	5.35	720	11.94
170	0.57	370	1.95	570	5.67	730	12.67
180	0.62	380	2.04	580	5.89		
190	0.65	390	2.11	590	6.18		

Average load vs. average displacement plot for Specimen S1R2 and S2R2 are shown in Figure 5.10. For S1R2 and S2R2 the values of average displacement are 7.81 mm and 12.67 mm and average ultimate load corresponding to displacement are 540 kN and 730 kN, respectively. The average displacement at ultimate load of specimen S2R2 are increased by 62 % compared to specimen S1R2.

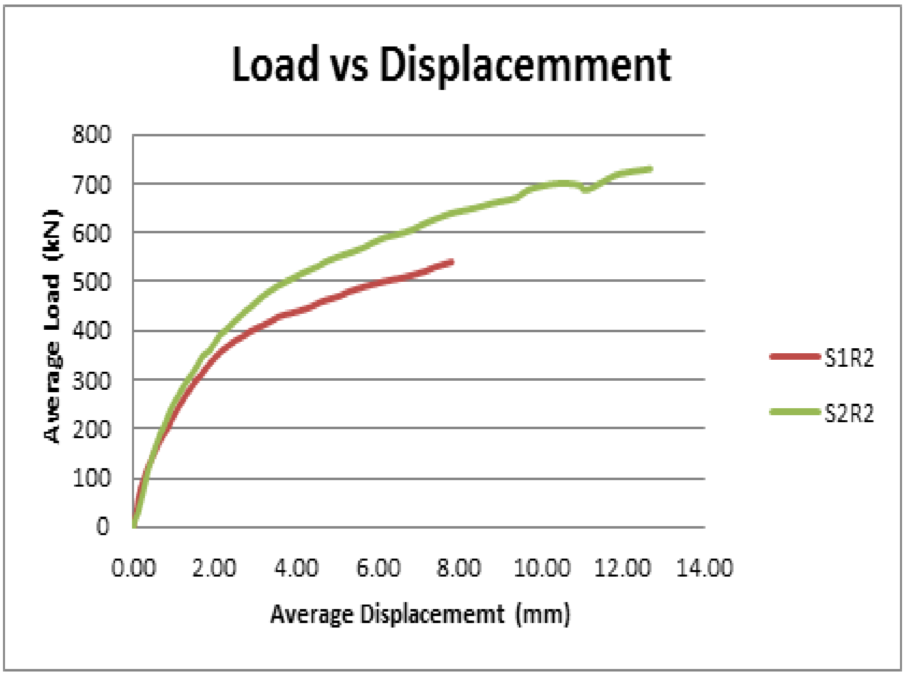


Figure 5.10: R2 corner radius specimen with single layer and double layers

Table 5.10 shows average displacement at average ultimate failure load for specimen S1R3.

Table 5.10: Average displacement of specimen S1R3

Specimen S1R3					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	170	0.34	340	1.05
10	0.01	180	0.38	350	1.13
20	0.03	190	0.41	360	1.20
30	0.04	200	0.43	370	1.26
40	0.05	210	0.47	380	1.36
50	0.07	220	0.50	390	1.47
60	0.08	230	0.53	400	1.56
70	0.11	240	0.56	410	1.67
80	0.12	250	0.59	420	1.76
90	0.15	260	0.62	430	1.92
100	0.17	270	0.69	440	2.03
110	0.19	280	0.73	450	2.16
120	0.21	290	0.77	460	2.35
130	0.23	300	0.82	470	2.53
140	0.26	310	0.87	480	2.91
150	0.28	320	0.93	490	3.31
160	0.31	330	0.98	500	3.64

Table 5.11 shows average displacement at average ultimate failure load for specimen S2R3.

Table 5.11: Average displacement of specimen S2R3

Specimen S2R3					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	230	1.17	460	4.12
10	0.05	240	1.22	470	4.42
20	0.12	250	1.29	480	4.68
30	0.19	260	1.36	490	4.98
40	0.22	270	1.44	500	5.35
50	0.26	280	1.50	510	5.73
60	0.30	290	1.56	520	6.14
70	0.35	300	1.65	530	6.48
80	0.42	310	1.72	540	7.03
90	0.47	320	1.82	550	7.35
100	0.54	330	1.90	560	7.82
110	0.59	340	2.00	570	8.24
120	0.64	350	2.11	580	8.67
130	0.69	360	2.23	590	9.24
140	0.72	370	2.36	600	9.84
150	0.78	380	2.46	603	10.11
160	0.83	390	2.58	607	10.44
170	0.88	400	2.76	617	10.94
180	0.92	410	3.00	627	11.20
190	0.97	420	3.17	637	12.09
200	1.03	430	3.34	647	12.61
210	1.07	440	3.51	657	13.06
220	1.11	450	3.79	660	13.69

Figure 5.11 shows the average load vs. average displacement plot for specimen S1R3 and S2R3. For S1R3 and S2R3 the values of average displacement are 3.64 mm and 13.69 mm and average ultimate load corresponding to displacement are 500 kN and 660 kN, respectively. The average displacement at ultimate load of specimen S2R3 are increased by 276 % compared to specimen S1R3.

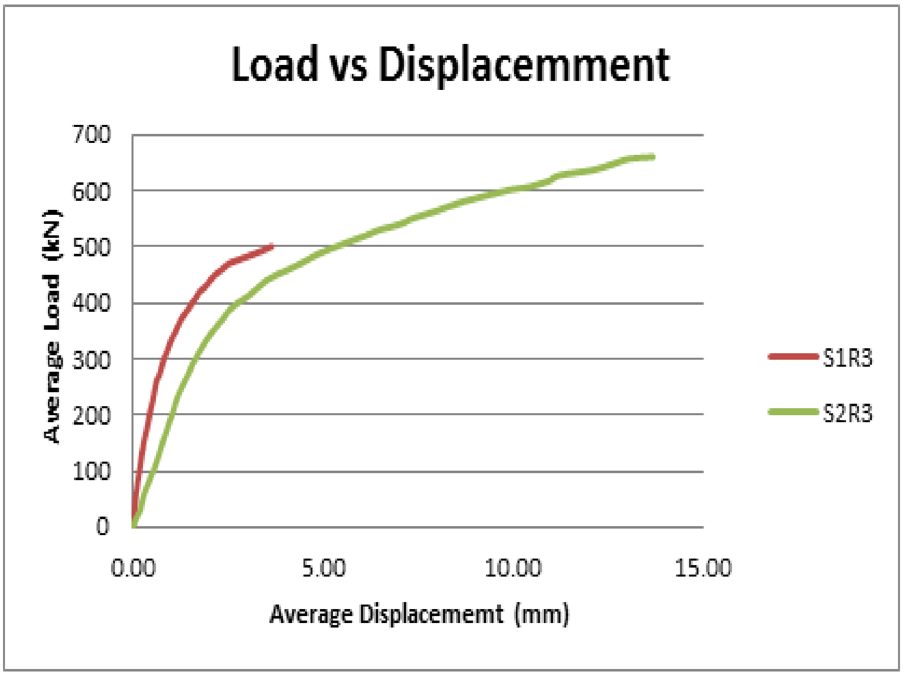


Figure 5.11: R3 corner radius specimen with single layer and double layers

Comparison of ultimate failure load vs. displacement keeping number of layers constant

Comparing specimens S1R0, S1R1, S1R2 and S1R3 keeping wrapping layer same that is one shown in Figure 5.12. In this case the average displacement at ultimate load of specimens S1R0 to S1R1, S1R1 to S1R2 and S1R2 to S1R3 are vary 5 %, 26 % and - 53 % respectively. As increasing the radius with one layer of wrapping the displacement of specimens are more except for specimen S1R3. Specimen S1R3 fails on lower loads due to premature failure of specimen therefore the displacement value shows in plot is less than the other specimen.

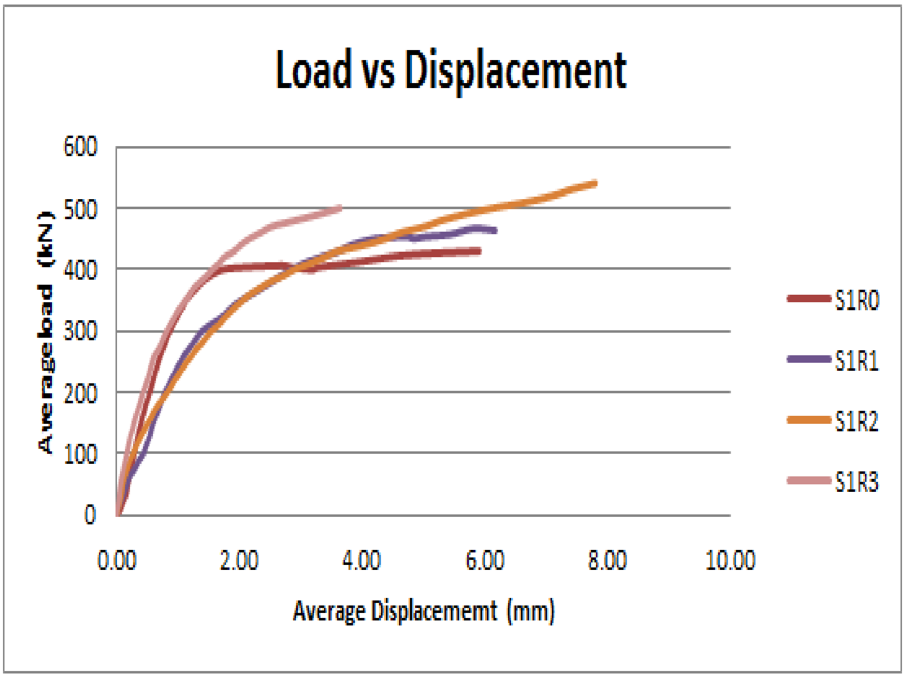


Figure 5.12: Single layer wrapped specimen with different corner radii

Figure 5.13 shows comparing the specimen S2R0, S2R1, S2R2 and S2R3 keeping wrapping layer same which is two. For specimens S2R0 to S2R1, S2R1 to S2R2 and S2R2 to S2R3 are varying 11 %, 14 % and 8 % respectively for the average displacement at ultimate load. As the number of layers are two the specimen shows more displacement than single layer wrapped specimens.

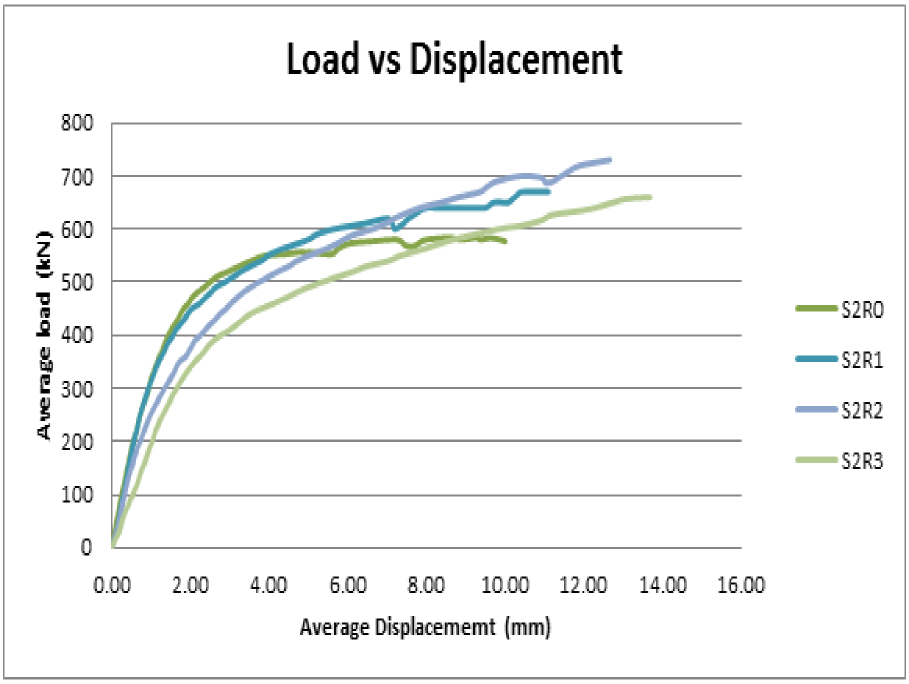


Figure 5.13: Double layer wrapped specimen with different corner radii

Figure 5.12 and Figure 5.13 shows plot of average ultimate load vs. average displacement which indicate that as the radius increased towards 0 mm to 35 mm radius the average value of increment of displacement is ranging from 5 to 26 % for single layer and 8 to 14 % for double layers respectively.

5.5 Axial Stress vs. Strain

Strain is measured in axial direction and lateral direction with the help of LVDT and electrical strain gauges respectively. For measuring axial strain the gauge length is for LVDT setup is 800 mm. Strain is measured in lateral direction on mid height of the column which is 600 mm. As discussed in previous chapter 4, stain gauges are located at on concrete surface and on FRP surface for different corner radius is shown in Figure 4.23. Table 5.12 to Table 5.20 shows the results of average axial stress, average axial strain and average lateral strain. Axial stress, axial strain and lateral strain readings for all the columns are individually shown in tabular form in Appendix A.

Table 5.12: Average results for S0R0 - axial stress, axial strain and lateral strain

Specimen S0R0			
Axial stress N/mm^2	Axial strain	lateral Strain	
		Mid	Corner
0.00	0.00000	0.00000	-0.00001
0.64	0.00002	0.00003	0.00001
1.28	0.00005	0.00005	0.00002
1.92	0.00007	0.00005	0.00003
2.56	0.00009	0.00005	0.00002
3.20	0.00011	0.00005	0.00002
3.84	0.00013	0.00006	0.00003
4.48	0.00017	0.00007	0.00004
5.12	0.00020	0.00008	0.00004
5.76	0.00023	0.00010	0.00005
6.40	0.00026	0.00012	0.00005
7.04	0.00029	0.00011	0.00006
7.68	0.00032	0.00012	0.00007
8.32	0.00035	0.00013	0.00008
8.96	0.00037	0.00013	0.00010
9.60	0.00039	0.00015	0.00012
10.24	0.00042	0.00016	0.00013
10.88	0.00044	0.00017	0.00015
11.52	0.00046	0.00018	0.00017
12.16	0.00049	0.00018	0.00019
12.80	0.00050	0.00019	0.00023
13.44	0.00053	0.00019	0.00024
14.08	0.00056	0.00019	0.00028
14.72	0.00060	0.00022	0.00031
15.36	0.00062	0.00024	0.00034
16.00	0.00065	0.00037	0.00038
16.64	0.00068	0.00044	0.00042
17.28	0.00073	0.00048	0.00044
17.92	0.00076	0.00052	0.00007
18.56	0.00079	0.00059	-0.00004

Table 5.13: Average results for S1R0 - axial stress, axial strain and lateral strain

Specimen S1R0			
Axial stress N/mm^2	Axial strain	lateral Strain	
		Mid	Corner
0.00	0.00000	0.00000	-0.00001
0.64	0.00008	0.00000	0.00000
1.28	0.00013	0.00001	0.00000
1.92	0.00018	0.00001	0.00000
2.56	0.00021	0.00002	-0.00001
3.20	0.00023	0.00002	-0.00001
3.85	0.00026	0.00002	-0.00001
4.49	0.00028	0.00002	-0.00001
5.13	0.00031	0.00003	-0.00001
5.77	0.00034	0.00003	-0.00001
6.41	0.00036	0.00003	-0.00001
7.05	0.00039	0.00004	-0.00001
7.69	0.00041	0.00004	-0.00001
8.33	0.00044	0.00004	0.00000
8.97	0.00047	0.00005	0.00000
9.61	0.00050	0.00005	0.00001
10.25	0.00053	0.00006	0.00001
10.89	0.00057	0.00007	0.00002
11.54	0.00060	0.00007	0.00002
12.18	0.00064	0.00008	0.00003
12.82	0.00068	0.00009	0.00004
13.46	0.00071	0.00010	0.00004
14.10	0.00075	0.00010	0.00004
14.74	0.00078	0.00011	0.00005
15.38	0.00082	0.00012	0.00006
16.02	0.00085	0.00013	0.00007
16.66	0.00090	0.00015	0.00007
17.30	0.00094	0.00016	0.00007
17.94	0.00099	0.00019	0.00009
18.58	0.00103	0.00021	0.00009
19.23	0.00109	0.00024	0.00010
19.87	0.00115	0.00028	0.00010
20.51	0.00122	0.00032	0.00011
21.15	0.00128	0.00037	0.00012
21.79	0.00135	0.00043	0.00014
22.43	0.00142	0.00052	0.00016
23.07	0.00152	0.00061	0.00017

Specimen S1R0			
Axial stress N/mm^2	Axial strain	lateral Strain	
		Mid	Corner
23.71	0.00164	0.00074	0.00019
24.35	0.00175	0.00085	0.00020
24.99	0.00192	0.00106	0.00023
25.63	0.00215	0.00155	0.00027
25.85	0.00251	0.00179	0.00031
26.06	0.00340	0.00180	0.00037
25.85	0.00359	0.00169	0.00042
25.63	0.00402	0.00168	0.00044
25.85	0.00408	0.00174	0.00047
26.49	0.00501	0.00189	0.00049
27.13	0.00588	0.00350	0.00051
27.56	0.00739	0.00334	0.00065
27.34	0.00798	0.00343	0.00057
27.13	0.00917	0.00965	0.00040
27.34	0.01055	0.00955	0.00038

Table 5.14: Average results for S2R0 - axial stress, axial strain and lateral strain

Specimen S2R0			
Axial stress N/mm^2	Axial strain	lateral Strain	
		Mid	Corner
0.00	0.00000	0.00000	-0.00003
0.64	0.00002	-0.00001	-0.00007
1.28	0.00005	-0.00001	-0.00007
1.92	0.00009	0.00000	-0.00009
2.56	0.00012	-0.00001	-0.00009
3.20	0.00014	0.00000	-0.00010
3.85	0.00018	-0.00002	-0.00020
4.49	0.00022	-0.00001	-0.00021
5.13	0.00025	-0.00003	-0.00020
5.77	0.00028	-0.00003	-0.00019
6.41	0.00031	-0.00002	-0.00018
7.05	0.00035	-0.00002	-0.00016
7.69	0.00038	-0.00001	-0.00014
8.33	0.00042	-0.00001	-0.00007
8.97	0.00045	-0.00003	-0.00002
9.61	0.00048	-0.00002	0.00002
10.25	0.00053	-0.00001	0.00008
10.89	0.00055	-0.00001	0.00011
11.54	0.00060	-0.00001	0.00015
12.18	0.00063	0.00000	0.00025
12.82	0.00068	0.00000	0.00036
13.46	0.00073	0.00000	0.00044
14.10	0.00078	0.00000	0.00050
14.74	0.00081	0.00002	0.00062
15.38	0.00085	0.00002	0.00078
16.02	0.00090	0.00001	0.00092
16.66	0.00095	0.00002	0.00112
17.30	0.00100	0.00002	0.00124
17.94	0.00106	0.00004	0.00152
18.58	0.00113	0.00004	0.00178
19.23	0.00117	0.00003	0.00199
19.87	0.00121	0.00005	0.00224
20.51	0.00125	0.00004	0.00253
21.15	0.00132	0.00005	0.00254
21.79	0.00138	0.00006	0.00263
22.43	0.00145	0.00007	0.00263

Specimen S2R0			
Axial stress N/mm^2	Axial strain	lateral Strain	
		Mid	Corner
23.07	0.00151	0.00007	0.00277
23.71	0.00159	0.00009	0.00296
24.35	0.00165	0.00009	0.00313
24.99	0.00171	0.00011	0.00331
25.63	0.00180	0.00012	0.00343
26.28	0.00188	0.00013	0.00340
26.92	0.00198	0.00015	0.00275
27.56	0.00210	0.00017	0.00153
28.20	0.00218	0.00018	0.00120
28.84	0.00228	0.00020	0.00087
29.48	0.00243	0.00025	0.00065
30.12	0.00253	0.00027	0.00050
30.76	0.00270	0.00032	0.00029
31.40	0.00293	0.00038	0.00056
32.04	0.00312	0.00041	0.00061
32.68	0.00332	0.00046	0.00035
33.32	0.00369	0.00055	-0.00005
33.97	0.00405	0.00066	-0.00016
34.61	0.00442	0.00073	0.00059
35.25	0.00488	0.00083	0.00095
35.46	0.00553	0.00090	0.00175
35.67	0.00608	0.00093	0.00315
35.46	0.00632	0.00098	0.00521
35.67	0.00625	0.00101	0.00489
35.46	0.00700	0.00105	0.00502
36.10	0.00719	0.00106	0.00560
36.74	0.00757	0.00108	0.00622
36.96	0.00821	0.00119	0.00614
37.17	0.00908	0.00133	0.00568
36.53	0.00931	0.00138	0.00558
36.32	0.00951	0.00137	0.00600
36.53	0.00970	0.00140	0.00566
37.17	0.00998	0.00144	0.00533
37.38	0.01072	0.00150	0.00500
37.17	0.01113	0.00170	0.00416
37.38	0.01157	0.00178	0.00403
37.17	0.01174	0.00179	0.00322
37.38	0.01203	0.00184	0.00289
37.17	0.01234	0.00187	0.00258
36.96	0.01251	0.00193	0.00217

Table 5.15: Average results for S1R1 - axial stress, axial strain and lateral strain

Specimen S1R1					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	-0.00001	0.00000	-0.00001	0.00000
0.65	0.00002	-0.00002	0.00000	-0.00001	-0.00001
1.30	0.00007	-0.00002	0.00000	-0.00001	-0.00001
1.94	0.00013	-0.00003	0.00000	-0.00002	-0.00002
2.59	0.00017	-0.00002	0.00000	-0.00001	-0.00002
3.24	0.00021	-0.00003	0.00001	-0.00001	-0.00002
3.89	0.00025	-0.00003	0.00001	-0.00002	-0.00002
4.54	0.00033	-0.00003	0.00000	-0.00002	-0.00002
5.18	0.00040	-0.00003	0.00001	-0.00002	-0.00003
5.83	0.00046	-0.00003	0.00001	-0.00003	-0.00003
6.48	0.00055	-0.00003	0.00001	-0.00003	-0.00003
7.13	0.00059	-0.00003	0.00001	-0.00004	-0.00003
7.78	0.00063	-0.00003	0.00002	-0.00004	-0.00003
8.42	0.00068	-0.00003	0.00002	-0.00005	-0.00003
9.07	0.00071	-0.00003	0.00002	-0.00005	-0.00002
9.72	0.00074	-0.00003	0.00002	-0.00005	-0.00002
10.37	0.00079	-0.00003	0.00003	-0.00005	-0.00001
11.02	0.00085	-0.00002	0.00004	-0.00005	0.00000
11.66	0.00089	-0.00002	0.00004	-0.00004	0.00001
12.31	0.00094	-0.00001	0.00005	-0.00005	0.00002
12.96	0.00099	-0.00001	0.00006	-0.00004	0.00003
13.61	0.00105	-0.00001	0.00006	-0.00005	0.00004
14.26	0.00111	-0.00001	0.00007	-0.00005	0.00006
14.90	0.00118	0.00000	0.00008	-0.00004	0.00007
15.55	0.00124	0.00000	0.00008	-0.00004	0.00009
16.20	0.00131	0.00001	0.00010	-0.00004	0.00011
16.85	0.00138	0.00001	0.00010	-0.00004	0.00013
17.50	0.00147	0.00002	0.00012	-0.00004	0.00015
18.14	0.00156	0.00002	0.00013	-0.00004	0.00018
18.79	0.00165	0.00003	0.00014	-0.00004	0.00020
19.44	0.00174	0.00004	0.00016	-0.00004	0.00023
20.09	0.00190	0.00005	0.00018	-0.00004	0.00026
20.74	0.00210	0.00007	0.00021	-0.00003	0.00030
21.38	0.00225	0.00008	0.00024	-0.00004	0.00034
22.03	0.00238	0.00009	0.00027	-0.00003	0.00037
22.68	0.00255	0.00012	0.00031	-0.00002	0.00044

Specimen S1R1					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
23.33	0.00276	0.00014	0.00035	-0.00002	0.00049
23.98	0.00297	0.00016	0.00041	-0.00001	0.00057
24.62	0.00316	0.00020	0.00049	0.00001	0.00067
25.27	0.00335	0.00023	0.00056	0.00003	0.00076
25.92	0.00358	0.00028	0.00068	0.00007	0.00094
26.57	0.00381	0.00032	0.00078	0.00010	0.00106
27.22	0.00416	0.00041	0.00089	0.00014	0.00119
27.86	0.00453	0.00051	0.00097	0.00017	0.00133
28.51	0.00480	0.00060	0.00108	0.00020	0.00141
29.16	0.00526	0.00074	0.00128	0.00027	0.00164
29.38	0.00592	0.00073	0.00155	0.00038	0.00187
29.16	0.00606	0.00073	0.00164	0.00042	0.00184
29.38	0.00631	0.00075	0.00181	0.00052	0.00186
29.59	0.00678	0.00075	0.00192	0.00062	0.00192
30.24	0.00728	0.00081	0.00243	0.00083	0.00224
30.02	0.00772	0.00079	0.00256	0.00087	0.00216

Table 5.16: Average results for S2R1 - axial stress, axial strain and lateral strain

Specimen S2R1					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	-0.00001	0.00000	0.00001	-0.00001
0.65	0.00005	0.00000	0.00002	0.00002	0.00000
1.30	0.00011	0.00001	0.00003	0.00003	0.00001
1.94	0.00016	0.00002	0.00005	0.00004	0.00003
2.59	0.00019	0.00003	0.00005	0.00005	0.00004
3.24	0.00021	0.00004	0.00007	0.00005	0.00005
3.89	0.00024	0.00005	0.00008	0.00006	0.00008
4.54	0.00027	0.00005	0.00009	0.00007	0.00012
5.18	0.00030	0.00006	0.00010	0.00008	0.00014
5.83	0.00033	0.00007	0.00011	0.00009	0.00018
6.48	0.00037	0.00008	0.00013	0.00009	0.00026
7.13	0.00039	0.00010	0.00014	0.00010	0.00031
7.78	0.00043	0.00010	0.00016	0.00011	0.00037
8.42	0.00046	0.00011	0.00016	0.00012	0.00042
9.07	0.00049	0.00013	0.00018	0.00013	0.00045
9.72	0.00052	0.00013	0.00019	0.00013	0.00049
10.37	0.00056	0.00014	0.00020	0.00014	0.00054
11.02	0.00059	0.00016	0.00021	0.00015	0.00059
11.66	0.00062	0.00017	0.00023	0.00016	0.00065
12.31	0.00066	0.00018	0.00024	0.00017	0.00069
12.96	0.00070	0.00019	0.00026	0.00017	0.00076
13.61	0.00074	0.00020	0.00027	0.00018	0.00079
14.26	0.00078	0.00021	0.00029	0.00020	0.00080
14.90	0.00082	0.00022	0.00030	0.00020	0.00080
15.55	0.00086	0.00024	0.00032	0.00021	0.00084
16.20	0.00089	0.00025	0.00034	0.00022	0.00088
16.85	0.00095	0.00027	0.00035	0.00023	0.00095
17.50	0.00100	0.00028	0.00037	0.00024	0.00092
18.14	0.00106	0.00031	0.00039	0.00025	0.00091
18.79	0.00111	0.00033	0.00042	0.00026	0.00093
19.44	0.00116	0.00035	0.00043	0.00027	0.00092
20.09	0.00122	0.00037	0.00047	0.00028	0.00076
20.74	0.00129	0.00039	0.00050	0.00029	0.00068
21.38	0.00136	0.00042	0.00053	0.00031	0.00066
22.03	0.00141	0.00045	0.00056	0.00032	0.00067
22.68	0.00148	0.00048	0.00060	0.00034	0.00070
23.33	0.00157	0.00053	0.00065	0.00036	0.00066
23.98	0.00167	0.00057	0.00070	0.00038	0.00052

Specimen S2R1					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
24.62	0.00174	0.00062	0.00075	0.00040	0.00038
25.27	0.00183	0.00068	0.00082	0.00043	0.00026
25.92	0.00194	0.00076	0.00089	0.00046	0.00016
26.57	0.00203	0.00081	0.00094	0.00048	0.00019
27.22	0.00217	0.00090	0.00103	0.00052	0.00028
27.86	0.00230	0.00097	0.00110	0.00056	0.00043
28.51	0.00241	0.00104	0.00118	0.00059	0.00063
29.16	0.00254	0.00113	0.00127	0.00063	0.00102
29.81	0.00279	0.00131	0.00142	0.00071	0.00176
30.46	0.00296	0.00144	0.00154	0.00077	0.00260
31.10	0.00314	0.00157	0.00168	0.00084	0.00132
31.75	0.00329	0.00166	0.00177	0.00089	0.00108
32.40	0.00359	0.00187	0.00196	0.00102	-0.00017
33.05	0.00386	0.00204	0.00217	0.00113	-0.00137
33.70	0.00410	0.00222	0.00234	0.00126	-0.00293
34.34	0.00440	0.00238	0.00251	0.00140	-0.00481
34.99	0.00474	0.00256	0.00275	0.00156	-0.00557
35.64	0.00497	0.00268	0.00292	0.00165	-0.00553
36.29	0.00529	0.00283	0.00308	0.00177	-0.00574
36.94	0.00578	0.00303	0.00333	0.00198	-0.00611
37.58	0.00624	0.00323	0.00362	0.00221	-0.00619
38.23	0.00652	0.00336	0.00374	0.00238	-0.00628
38.88	0.00706	0.00356	0.00430	0.00265	-0.00621
39.53	0.00799	-0.00086	0.00452	0.00315	-0.00659
40.18	0.00876	-0.00222	0.00466	0.00356	-0.00647
39.53	0.00892	0.00286	0.00459	0.00362	-0.00639
38.88	0.00901	0.00435	0.00456	0.00364	-0.00634
39.53	0.00926	0.00450	0.00450	0.00375	-0.00623
40.18	0.00944	0.00466	0.00408	0.00387	-0.00593
40.82	0.00967	0.00482	0.00464	0.00402	-0.00574
41.47	0.00998	0.00491	0.00389	0.00422	-0.00548
41.47	0.01034	0.00278	0.00406	0.00431	-0.00516
41.47	0.01112	0.00248	0.00443	0.00455	-0.00482
41.47	0.01147	0.00249	0.00458	0.00463	-0.00467
41.47	0.01188	0.00526	0.00474	0.00471	-0.00450
42.12	0.01214	0.00553	0.00517	0.00478	-0.00432
42.12	0.01249	0.00568	0.00539	0.00490	-0.00415
42.12	0.01261	0.00581	0.00537	0.00498	-0.00401
42.77	0.01281	0.00590	0.00547	0.00509	-0.00399
43.42	0.01303	0.00595	0.00564	0.00526	-0.00389
43.42	0.01343	0.00605	0.00558	0.00535	-0.00380
43.42	0.01389	0.00389	0.00552	0.00544	-0.00368

Table 5.17: Average results for S1R2 - axial stress, axial strain and lateral strain

Specimen S1R2					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	-0.00001	-0.00001	-0.00002	-0.00001
0.66	0.00003	-0.00001	-0.00002	-0.00003	0.00000
1.33	0.00006	-0.00002	-0.00003	-0.00003	0.00001
1.99	0.00009	-0.00002	-0.00003	-0.00002	0.00003
2.65	0.00012	-0.00002	-0.00004	-0.00002	0.00004
3.31	0.00013	-0.00003	-0.00005	-0.00001	0.00006
3.98	0.00016	-0.00002	-0.00007	-0.00002	0.00007
4.64	0.00020	-0.00003	-0.00010	-0.00001	0.00009
5.30	0.00023	-0.00002	-0.00012	-0.00001	0.00012
5.96	0.00028	-0.00002	-0.00013	-0.00001	0.00014
6.63	0.00034	-0.00001	-0.00016	0.00001	0.00018
7.29	0.00039	-0.00001	-0.00018	0.00002	0.00021
7.95	0.00044	0.00000	-0.00020	0.00003	0.00022
8.62	0.00050	0.00001	-0.00021	0.00003	0.00024
9.28	0.00057	0.00001	-0.00021	0.00005	0.00025
9.94	0.00063	0.00002	-0.00021	0.00007	0.00026
10.60	0.00071	0.00004	-0.00021	0.00008	0.00027
11.27	0.00077	0.00004	-0.00022	0.00010	0.00028
11.93	0.00085	0.00005	-0.00021	0.00012	0.00029
12.59	0.00095	0.00006	-0.00020	0.00016	0.00030
13.25	0.00103	0.00007	-0.00018	0.00020	0.00032
13.92	0.00112	0.00008	-0.00019	0.00023	0.00034
14.58	0.00118	0.00009	-0.00018	0.00027	0.00036
15.24	0.00127	0.00011	-0.00017	0.00031	0.00038
15.91	0.00135	0.00013	-0.00016	0.00036	0.00041
16.57	0.00143	0.00015	-0.00015	0.00040	0.00045
17.23	0.00153	0.00017	-0.00013	0.00044	0.00049
17.89	0.00162	0.00020	-0.00011	0.00048	0.00052
18.56	0.00174	0.00023	-0.00003	0.00053	0.00059
19.22	0.00183	0.00027	0.00006	0.00056	0.00063
19.88	0.00193	0.00031	0.00010	0.00060	0.00070
20.54	0.00208	0.00034	0.00014	0.00064	0.00075
21.21	0.00218	0.00040	0.00017	0.00069	0.00082
21.87	0.00230	0.00046	0.00020	0.00074	0.00092
22.53	0.00243	0.00054	0.00025	0.00080	0.00101
23.20	0.00257	0.00064	0.00035	0.00086	0.00111

Specimen S1R2					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
23.86	0.00273	0.00075	0.00035	0.00093	0.00122
24.52	0.00293	0.00088	0.00039	-0.00004	0.00136
25.18	0.00313	0.00100	0.00043	0.00037	0.00148
25.85	0.00340	0.00116	0.00043	0.00115	0.00160
26.51	0.00362	0.00129	0.00042	-0.00038	0.00176
27.17	0.00394	0.00146	-0.00210	-0.00168	0.00189
27.83	0.00424	0.00172	-0.00209	-0.00217	0.00213
28.50	0.00451	0.00197	-0.00060	-0.00126	0.00221
29.16	0.00506	0.00252	-0.00234	-0.00244	0.00285
29.82	0.00548	0.00313	-0.00672	-0.00537	0.00228
30.49	0.00580	0.00361	-0.00879	-0.00705	0.00150
31.15	0.00629	0.00436	-0.01019	-0.00606	0.00105
31.81	0.00662	0.00478	-0.01060	-0.00917	0.00246
32.47	0.00710	0.00546	-0.01083	-0.01557	0.00231
33.14	0.00767	0.00618	-0.01156	-0.02396	0.00284
33.80	0.00837	0.00732	-0.01254	-0.01685	0.00275
34.46	0.00890	0.00827	-0.00839	-0.01469	0.00286
35.12	0.00926	0.00740	0.00845	-0.01341	0.00304
35.79	0.00976	0.00877	0.00861	-0.00922	0.00288

Table 5.18: Average results for S2R2 - axial stress, axial strain and lateral strain

Specimen S2R2					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	0.00001	0.00000	0.00000	0.00000
0.66	0.00003	0.00003	-0.00001	0.00001	0.00001
1.33	0.00008	0.00004	0.00000	0.00002	0.00001
1.99	0.00015	0.00007	0.00001	0.00003	0.00002
2.65	0.00018	0.00009	0.00001	0.00003	0.00002
3.31	0.00023	0.00012	0.00001	0.00004	0.00002
3.98	0.00027	0.00014	0.00000	0.00003	0.00002
4.64	0.00030	0.00016	0.00000	0.00004	0.00003
5.30	0.00033	0.00017	0.00001	0.00005	0.00003
5.96	0.00036	0.00020	0.00001	0.00005	0.00003
6.63	0.00040	0.00023	0.00001	0.00005	0.00004
7.29	0.00044	0.00026	0.00001	0.00005	0.00004
7.95	0.00048	0.00029	0.00001	0.00006	0.00004
8.62	0.00052	0.00033	0.00002	0.00007	0.00005
9.28	0.00057	0.00036	0.00002	0.00008	0.00005
9.94	0.00062	0.00040	0.00002	0.00009	0.00007
10.60	0.00067	0.00046	0.00001	0.00011	0.00008
11.27	0.00071	0.00050	0.00002	0.00013	0.00008
11.93	0.00077	0.00055	0.00003	0.00014	0.00010
12.59	0.00082	0.00059	0.00004	0.00015	0.00010
13.25	0.00090	0.00065	0.00004	0.00016	0.00012
13.92	0.00096	0.00071	0.00003	0.00018	0.00013
14.58	0.00103	0.00076	0.00003	0.00019	0.00014
15.24	0.00109	0.00084	0.00002	0.00021	0.00017
15.91	0.00115	0.00091	0.00002	0.00023	0.00018
16.57	0.00122	0.00099	0.00002	0.00025	0.00019
17.23	0.00131	0.00110	0.00001	0.00027	0.00021
17.89	0.00140	0.00120	0.00001	0.00030	0.00023
18.56	0.00148	0.00131	0.00003	0.00033	0.00026
19.22	0.00157	0.00146	0.00004	0.00037	0.00029
19.88	0.00167	0.00158	0.00007	0.00041	0.00033
20.54	0.00178	0.00176	0.00011	0.00046	0.00036
21.21	0.00187	0.00192	0.00015	0.00050	0.00039
21.87	0.00197	0.00213	0.00023	0.00054	0.00043
22.53	0.00205	0.00232	0.00026	0.00058	0.00047

Specimen S2R2					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
23.20	0.00215	0.00260	0.00028	0.00063	0.00052
23.86	0.00235	0.00301	0.00035	0.00070	0.00057
24.52	0.00244	0.00347	0.00043	0.00076	0.00063
25.18	0.00255	0.00383	0.00052	0.00081	0.00069
25.85	0.00264	0.00421	0.00057	0.00087	0.00074
26.51	0.00281	0.00478	0.00067	0.00095	0.00082
27.17	0.00297	0.00537	0.00074	0.00101	0.00088
27.83	0.00311	0.00580	0.00084	0.00108	0.00095
28.50	0.00328	0.00669	0.00096	0.00117	0.00104
29.16	0.00344	0.00761	0.00115	0.00129	0.00116
29.82	0.00362	0.00830	0.00118	0.00142	0.00130
30.49	0.00379	0.00859	0.00120	0.00155	0.00144
31.15	0.00396	0.00867	0.00109	0.00164	0.00153
31.81	0.00416	0.00892	0.00104	0.00176	0.00165
32.47	0.00440	0.00946	0.00107	0.00192	0.00183
33.14	0.00468	0.01000	0.00161	0.00208	0.00200
33.80	0.00498	0.01087	0.00274	0.00225	0.00212
34.46	0.00527	0.01123	0.00323	0.00244	0.00228
35.12	0.00563	0.01163	0.00379	0.00264	0.00242
35.79	0.00588	0.01286	0.00419	0.00280	0.00260
36.45	0.00625	0.01444	0.00465	0.00300	0.00282
37.11	0.00669	0.01594	0.00610	0.00324	0.00304
37.78	0.00708	0.01647	0.00634	0.00345	0.00326
38.44	0.00736	0.01720	0.00756	0.00366	0.00327
39.10	0.00772	0.01772	0.00869	0.00386	0.00370
39.76	0.00830	0.01799	0.01068	0.00409	0.00341
40.43	0.00868	0.01822	0.01055	0.00420	0.00353
41.09	0.00898	0.01844	0.01055	0.00430	0.00210

Table 5.19: Average results for S1R3 - axial stress, axial strain and lateral strain

Specimen S1R3					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	-0.00001	0.00000	0.00000	0.00002
0.69	0.00002	0.00000	0.00001	0.00001	0.00004
1.37	0.00004	0.00000	0.00001	0.00001	0.00006
2.06	0.00005	0.00000	0.00002	0.00002	0.00010
2.74	0.00007	0.00000	0.00002	0.00002	0.00012
3.43	0.00008	0.00000	0.00002	0.00002	0.00013
4.12	0.00010	-0.00001	0.00002	0.00002	0.00030
4.80	0.00013	-0.00001	0.00002	0.00002	0.00035
5.49	0.00015	-0.00001	0.00002	0.00003	0.00038
6.18	0.00018	-0.00002	0.00003	0.00002	0.00041
6.86	0.00021	-0.00002	0.00003	0.00003	0.00044
7.55	0.00024	-0.00002	0.00004	0.00003	0.00047
8.23	0.00026	-0.00002	0.00004	0.00004	0.00049
8.92	0.00029	-0.00002	0.00004	0.00004	0.00051
9.61	0.00033	-0.00002	0.00005	0.00005	0.00053
10.29	0.00035	-0.00001	0.00005	0.00006	0.00055
10.98	0.00039	-0.00001	0.00006	0.00006	0.00057
11.67	0.00043	-0.00001	0.00006	0.00006	0.00060
12.35	0.00047	-0.00001	0.00007	0.00007	0.00063
13.04	0.00051	-0.00001	0.00007	0.00007	0.00064
13.72	0.00054	0.00000	0.00008	0.00007	0.00067
14.41	0.00058	-0.00001	0.00008	0.00008	0.00070
15.10	0.00062	0.00000	0.00009	0.00008	0.00071
15.78	0.00066	0.00001	0.00009	0.00009	0.00072
16.47	0.00070	0.00001	0.00010	0.00009	0.00074
17.16	0.00073	0.00002	0.00010	0.00010	0.00075
17.84	0.00077	0.00003	0.00011	0.00010	0.00077
18.53	0.00086	0.00004	0.00012	0.00011	0.00078
19.21	0.00091	0.00006	0.00013	0.00012	0.00080
19.90	0.00096	0.00008	0.00015	0.00012	0.00082
20.59	0.00103	0.00011	0.00016	0.00013	0.00085
21.27	0.00109	0.00013	0.00018	0.00014	0.00089
21.96	0.00116	0.00021	0.00021	0.00015	0.00097
22.64	0.00123	0.00021	0.00022	0.00016	0.00099
23.33	0.00132	0.00026	0.00024	0.00018	0.00105

Specimen S1R3					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
24.02	0.00141	0.00030	0.00027	0.00020	0.00112
24.70	0.00150	0.00037	0.00031	0.00022	0.00125
25.39	0.00157	0.00043	0.00035	0.00024	0.00134
26.08	0.00170	0.00051	0.00040	0.00027	0.00151
26.76	0.00184	0.00057	0.00045	0.00030	0.00164
27.45	0.00195	0.00065	0.00050	0.00034	0.00180
28.13	0.00209	0.00080	0.00061	0.00039	0.00212
28.82	0.00220	0.00091	0.00069	0.00043	0.00236
29.51	0.00240	0.00099	0.00080	0.00049	0.00259
30.19	0.00253	0.00110	0.00089	0.00056	0.00282
30.88	0.00270	0.00137	0.00113	0.00075	0.00342
31.57	0.00294	0.00182	0.00148	0.00105	0.00419
32.25	0.00317	0.00215	0.00144	0.00126	0.00474
32.94	0.00364	0.00239	0.00161	0.00145	0.00515
33.62	0.00413	0.00259	0.00174	0.00167	0.00565
34.31	0.00455	0.00296	0.00198	0.00204	0.00633

Table 5.20: Average results for S2R3 - axial stress, axial strain and lateral strain

Specimen S2R3					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
0.00	0.00000	0.00000	0.00000	0.00000	0.00000
0.69	0.00006	0.00001	0.00000	-0.00001	0.00000
1.37	0.00015	0.00002	0.00000	-0.00001	0.00000
2.06	0.00024	0.00003	0.00000	0.00000	0.00001
2.74	0.00028	0.00003	0.00000	0.00000	0.00001
3.43	0.00032	0.00004	0.00000	0.00000	0.00000
4.12	0.00037	0.00004	0.00000	0.00000	-0.00001
4.80	0.00044	0.00004	0.00000	-0.00001	-0.00001
5.49	0.00052	0.00005	0.00000	0.00000	-0.00001
6.18	0.00058	0.00006	0.00000	0.00000	0.00000
6.86	0.00067	0.00007	0.00001	0.00001	0.00003
7.55	0.00073	0.00008	0.00001	0.00001	0.00007
8.23	0.00080	0.00009	0.00001	0.00002	0.00012
8.92	0.00086	0.00011	0.00002	0.00002	0.00019
9.61	0.00090	0.00012	0.00002	0.00002	0.00027
10.29	0.00097	0.00013	0.00003	0.00004	0.00039
10.98	0.00104	0.00015	0.00003	0.00004	0.00047
11.67	0.00110	0.00016	0.00004	0.00006	0.00054
12.35	0.00115	0.00018	0.00005	0.00007	0.00062
13.04	0.00121	0.00019	0.00005	0.00008	0.00069
13.72	0.00128	0.00020	0.00005	0.00010	0.00513
14.41	0.00134	0.00021	0.00006	0.00011	0.00532
15.10	0.00138	0.00023	0.00006	0.00013	0.00539
15.78	0.00146	0.00025	0.00007	0.00014	0.00538
16.47	0.00153	0.00027	0.00008	0.00016	0.00539
17.16	0.00161	0.00030	0.00010	0.00018	0.00538
17.84	0.00170	0.00034	0.00011	0.00020	0.00537
18.53	0.00180	0.00038	0.00012	0.00023	0.00535
19.21	0.00187	0.00041	0.00014	0.00025	0.00535
19.90	0.00195	0.00044	0.00016	0.00027	0.00536
20.59	0.00206	0.00048	0.00017	0.00029	0.00539
21.27	0.00215	0.00053	0.00019	0.00033	0.00541
21.96	0.00227	0.00057	0.00021	0.00036	0.00543
22.64	0.00237	0.00064	0.00024	0.00039	0.00547
23.33	0.00250	0.00069	0.00027	0.00042	0.00549

Specimen S2R3					
Axial stress N/mm^2	Axial strain	lateral Strain			
		Mid	Left	Center	Right
24.02	0.00264	0.00076	0.00029	0.00046	0.00554
24.70	0.00279	0.00083	0.00032	0.00050	0.00559
25.39	0.00295	0.00090	0.00036	0.00053	0.00565
26.08	0.00307	0.00097	0.00039	0.00056	0.00570
26.76	0.00323	0.00106	0.00042	0.00061	0.00576
27.45	0.00345	0.00118	0.00050	0.00069	0.00588
28.13	0.00375	0.00136	0.00060	0.00077	0.00597
28.82	0.00396	0.00156	0.00065	0.00083	0.00557
29.51	0.00417	0.00172	0.00072	0.00088	0.00585
30.19	0.00439	0.00185	0.00079	0.00094	0.00562
30.88	0.00473	0.00209	0.00088	0.00102	0.00610
31.57	0.00515	0.00237	0.00098	0.00111	0.00621
32.25	0.00552	0.00254	0.00100	0.00125	0.00597
32.94	0.00585	0.00271	0.00054	0.00135	0.00582
33.62	0.00622	0.00287	0.00114	0.00145	0.00576
34.31	0.00669	0.00310	0.00097	0.00159	0.00482
35.00	0.00717	0.00331	0.00135	0.00175	0.00544
35.68	0.00767	0.00342	0.00156	0.00191	0.00597
36.37	0.00810	0.00363	0.00175	0.00211	0.00495
37.05	0.00879	0.00390	0.00207	0.00239	0.00541
37.74	0.00918	0.00409	0.00221	0.00252	0.00470
38.43	0.00978	0.00435	0.00255	0.00274	0.00558
39.11	0.01030	0.00429	0.00255	0.00292	0.00625
39.80	0.01084	0.00425	-0.00015	0.00305	0.00623
40.49	0.01155	0.00435	-0.00010	0.00325	0.00554
41.17	0.01230	0.00456	0.00249	0.00346	0.00584
41.40	0.01264	0.00465	0.00379	0.00361	0.00560
41.63	0.01305	0.00464	0.00387	0.00370	0.00592
42.32	0.01367	0.00463	0.00384	0.00385	0.00508
43.00	0.01400	0.00464	0.00394	0.00392	0.00494
43.69	0.01511	0.00487	0.00418	0.00410	0.00583

5.5.1 Axial Stress vs. Axial Strain

Comparing specimen S0R0, S1R0 and S2R0 keeping corner radius same R0 and varying wrapping layers. Figure 5.14 shows the average axial stress vs. axial strain plot, S0R0, S1R0 and S2R0 are subjected to total stress of 18.56 N/mm^2, 27.34 N/mm^2 and 36.96 N/mm^2 and strain observed are 0.0007, 0.0100 and 0.0125 respectively. Ultimate stress observed in S1R0 and S2R0 are 27.34 N/mm^2 and 36.96 N/mm^2 which are 47 % and 99 % higher than S0R0 respectively. From the plot for specimen S1R0 and S2R0, the axial strain is same up to axial stress of 25 N/mm^2.

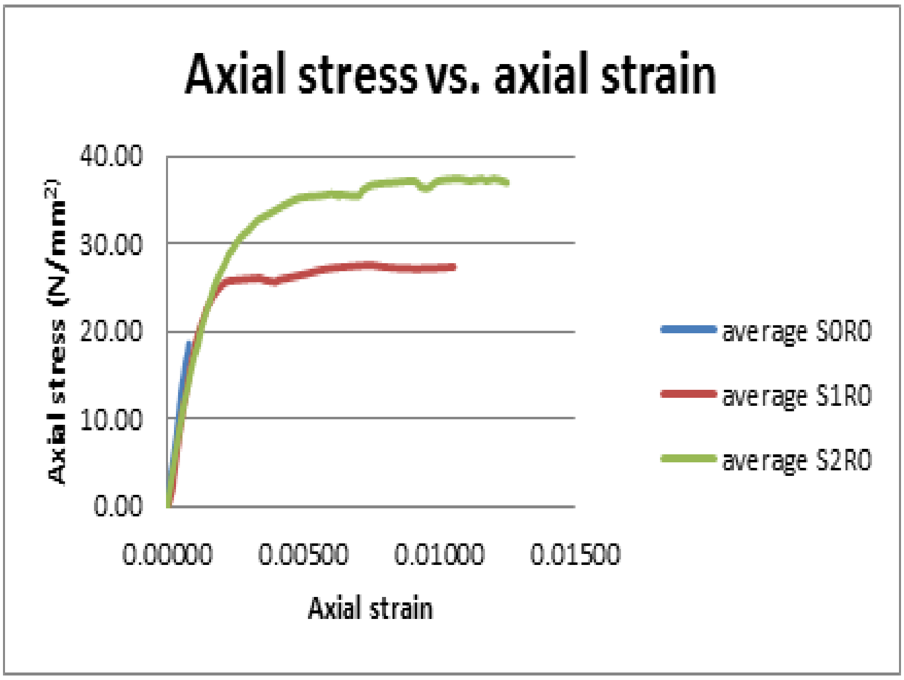


Figure 5.14: R0 corner radius with one layer and two layers

For specimen S1R1 and S2R1 keeping corner radius same R1 and varying wrapping layer that are one and two. Figure 5.15 shows the average axial stress vs. axial strain plot, S1R1 and S2R1 are subjected to total stress of 30.02 N/mm^2 and 43.42 N/mm^2 and strain observed are 0.0077 and 0.0138 respectively. Ultimate stress of S2R1 is 45 % higher than S1R1.

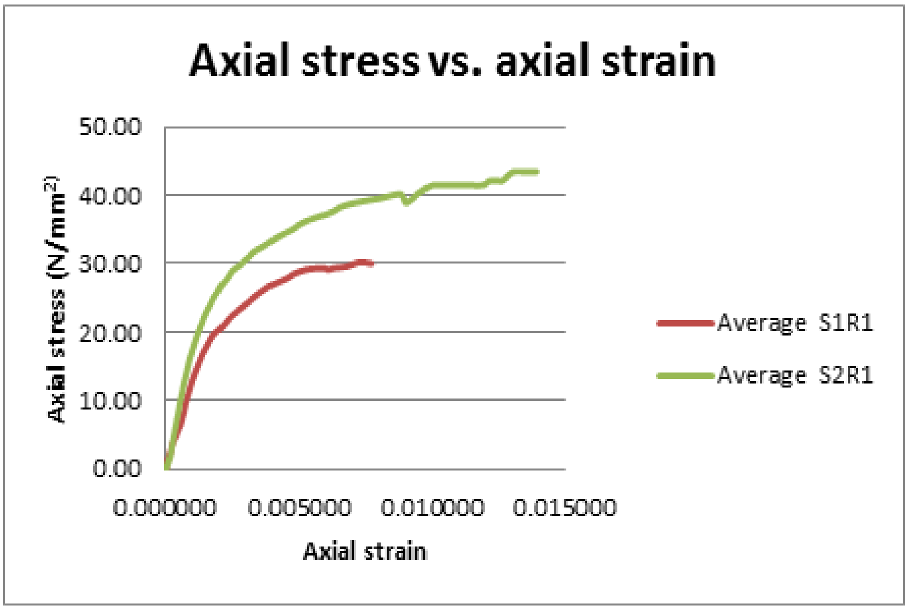


Figure 5.15: R1 corner radius with one layer and two layers

Figure 5.16 shows the average axial stress vs. axial strain plot, S1R2 and S2R2 are subjected to total stress of 35.79 N/mm^2 and 41.09 N/mm^2 and strain observed are 0.0097 and 0.0089 respectively. Ultimate stress of S2R2 is 15 % higher than S1R2. From the plot for specimen S1R2 and S2R2, the axial strain is same up to axial stress of 13 N/mm^2.

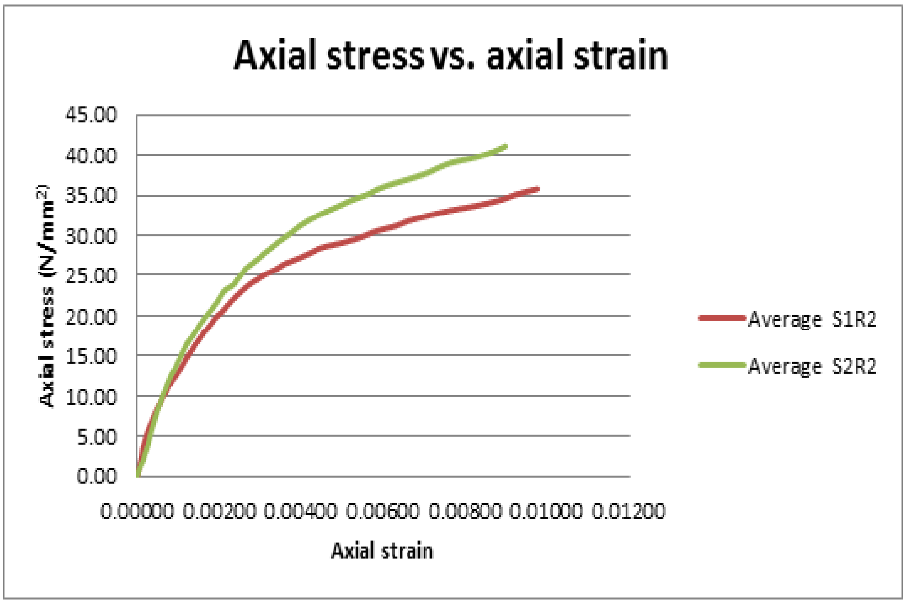


Figure 5.16: R2 corner radius with one layer and two layers

Figure 5.17 shows the average axial stress vs. axial strain plot, S1R3 and S2R3 are subjected to total stress of 34.31 N/mm^2 and 43.69 N/mm^2 and strain observed are 0.0045 and 0.0151 respectively. Ultimate stress observed higher than S1R3 for specimen S2R3 which is 27 %.

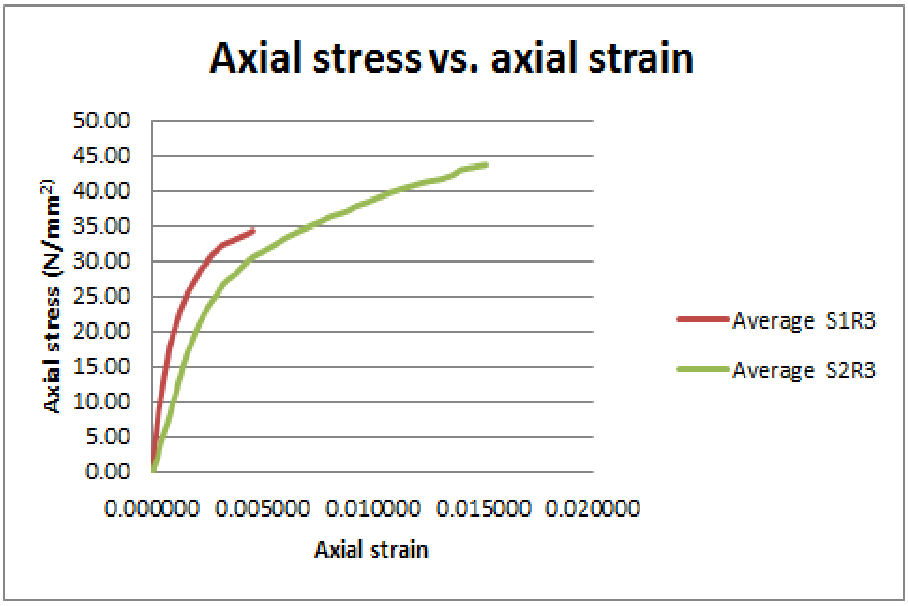


Figure 5.17: R3 corner radius with one layer and two layers

Figure 5.21 shows average axial stress vs. axial strain plot for specimens S1R0, S1R1, S1R2 and S1R3. For specimen S1R0, S1R1, S1R2 and S1R3 are subjected to stress of 27.34 N/mm^2, 30.02 N/mm^2, 35.79 N/mm^2 and 34.31 N/mm^2 and strain observed are 0.0105, 0.0077, 0.0098 and 0.0045 respectively. Ultimate stress observed in percentage comparing between S1R0 to S1R1, S1R1 to S1R2 and S1R2 to S1R3 are 10 %, 19 % and - 4 % varying respectively. Specimens S1R1 and S1R2 are show same axial strain up to axial stress of 30 N/mm^2.

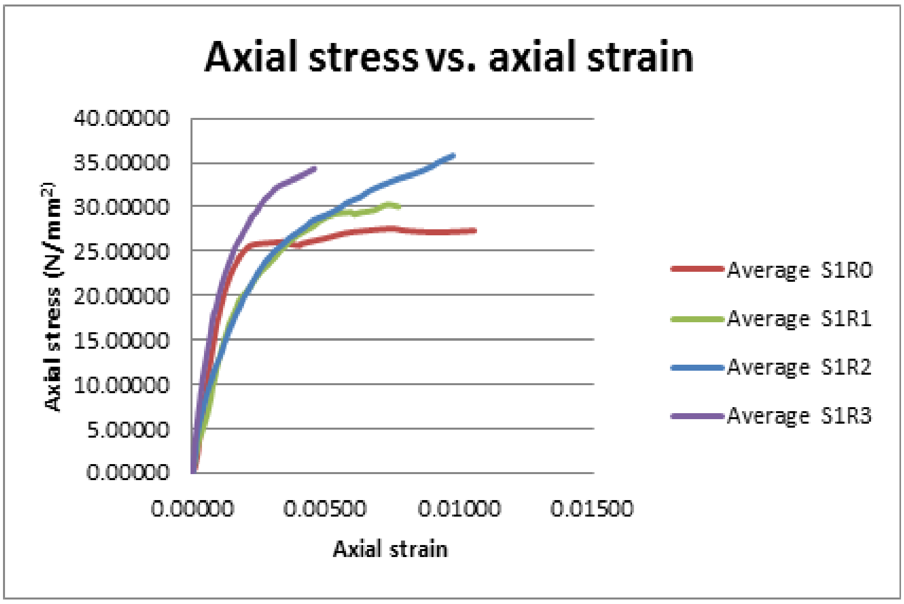


Figure 5.18: Single layer with different corner radius

Figure 5.19 shows average axial stress vs. axial strain plot for specimens S2R0, S2R1, S2R2 and S2R3. For specimen S2R0, S2R1, S2R2 and S2R3 are subjected to stress of 36.96 N/mm^2, 43.42 N/mm^2, 41.09 N/mm^2 and 43.69 N/mm^2 and strain observed are 0.0125, 0.0138, 0.0089 and 0.0151 respectively. Ultimate stress observed in percentage comparing between S2R0 to S2R1, S2R1 to S2R2 and S2R2 to S2R3 are 17 %, - 5 % and 6 % varying respectively. Specimens S2R0 and S2R1 are show same axial strain up to axial stress of 25 N/mm^2.

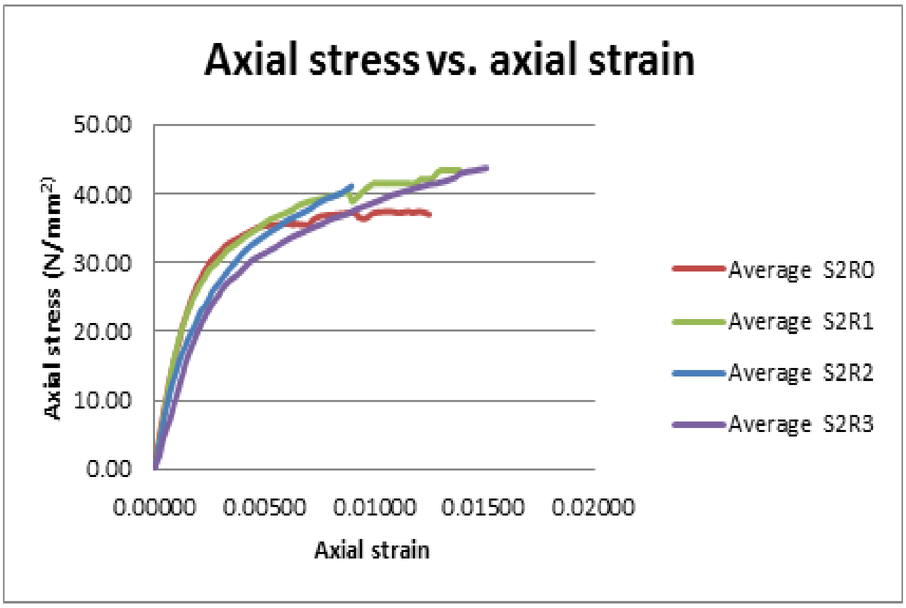


Figure 5.19: Double layers with different corner radius

5.5.2 Axial Stress vs. Lateral Strain

Figure 5.20 shows the plot of axial stress vs. lateral strain for the specimen S2R2. Lateral strain measured at the mid of side face and left, center and right on corner radius. Plot shows that strain is more at mid and then in decreasing left, right points and at the center. Specimen S2R2 is subjected to total stress of 41.09 N/mm^2 and strain observed at mid, left, center and right is 0.0045, 0.0029, 0.0017 and 0.0050 respectively. After debonding of FRP at axial stress 30 N/mm^2 the strain developed in right is more as shown from the graphical plot. Strain developed in mid is more from the starting of the axial stress. From the strain results it is clear that strain developed in Specimen S2R2 at mid is more than left and right points and same left and right points results are more than the center one, which shows the ideal condition.

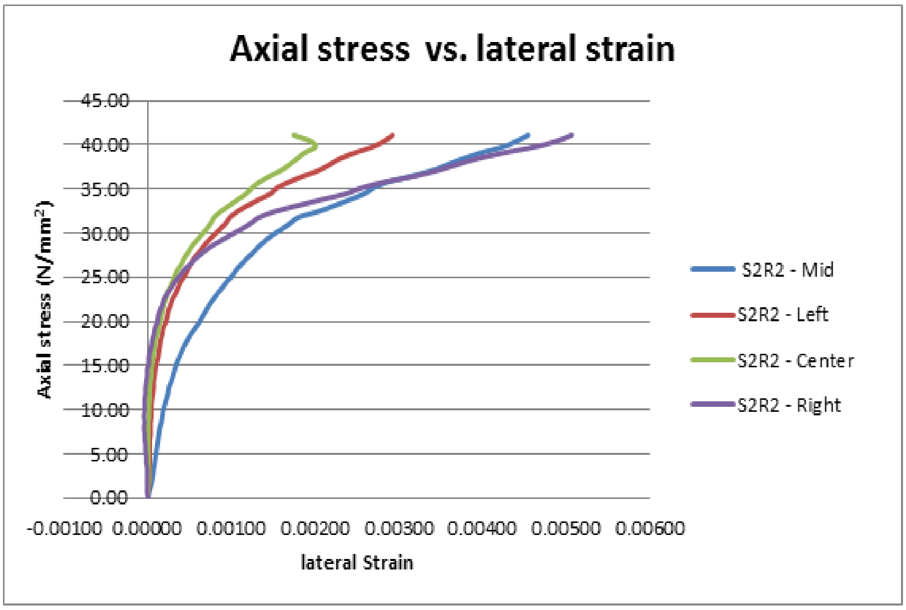


Figure 5.20: Strain at mid, left, Center and Right of S2R2

Figure 5.21 shows a plot of average axial stress vs. lateral strain for specimens S1R0, S1R1, S1R2 and S1R3. For plotting of graph only mid-point is consider as at mid-point the value of strain is more than other points. For specimen S1R0, S1R1, S1R2 and S1R3 are subjected to stress of 27.34 N/mm^2, 30.02 N/mm^2, 35.79 N/mm^2 and 34.31 N/mm^2 and strain observed are 0.0105, 0.0077, 0.0097 and 0.0045 respectively. Ultimate stress observed in percentage comparing between S1R0 to S1R1, S1R1 to S1R2 and S1R2 to S1R3 are 10 %, 19 % and - 4 % varying respectively.

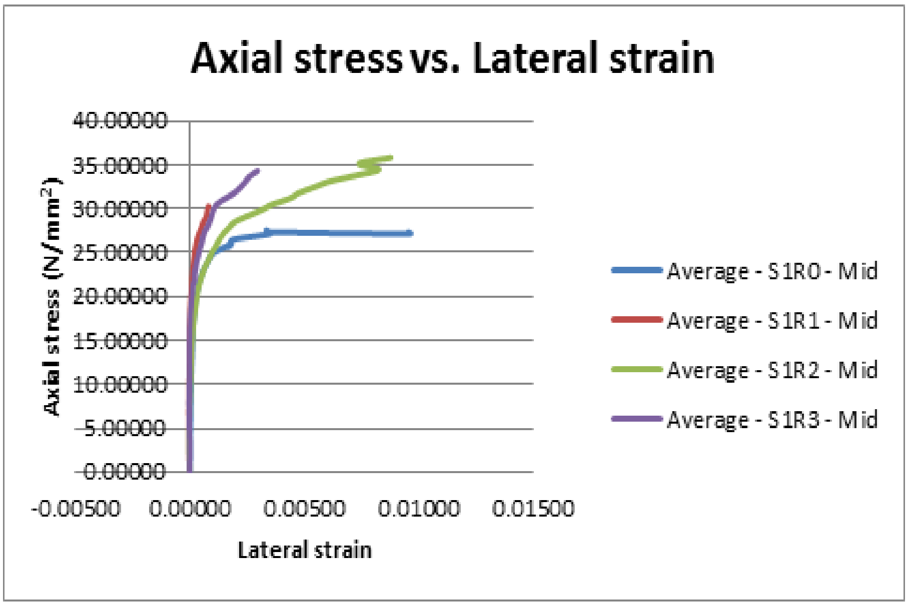


Figure 5.21: Single layer with different corner radius

Figure 5.22 shows a plot of average axial stress vs. lateral strain for specimens S2R0, S2R1, S2R2 and S2R3. For specimen S2R0, S2R1, S2R2 and S2R3 are subjected to stress of 36.96 N/mm^2, 43.42 N/mm^2, 41.09 N/mm^2 and 43.69 N/mm^2 and strain observed are 0.0125, 0.0138, 0.0089 and 0.0151 respectively. Ultimate stress observed in percentage comparing between S2R0 to S2R1, S2R1 to S2R2 and S2R2 to S2R3 are 17 %, - 5 % and 6 % varying respectively.

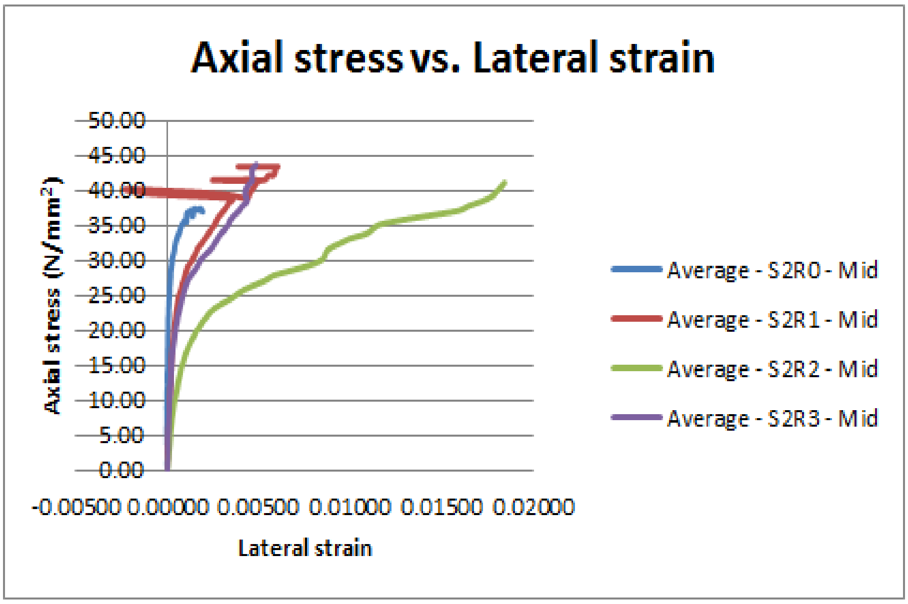


Figure 5.22: Double layer with different corner radius

5.6 Corner Radius Effect

Table 5.21 shows the mean value of the compressive strength of the 3 specimens and the corresponding strength gain of confined concrete f_{cc}/f_{co}. [7]

Where,

f_{cc} = Mean compressive strength of GFRP confined concrete columns

= ultimate load / Area

= (486.67 × 1000) / 15432 From Table 5.1 for S1R1

= 31.54 N/mm^2

f_{co} = Mean compressive strength of the unconfined control columns

$= 20.57$ N/mm^2 From Table 4.2

r = Corner radius

b = Width of section

Maximum values of f_{cc}/f_{co} for single layer and two layers GFRP confined specimens 1.85 and 2.22 respectively.

Table 5.21: Mean compressive strengths and corresponding f_{cc}/f_{co}

Notation	Corner radius	b	Corner radius ratio 2r/b	Unconfined f_{co}	Confined f_{cc}		f_{cc} / f_{co}
					1 layer	2 layers	
S1R0	0	125	0.00	20.57	28.63	-	1.39
S1R1	15	125	0.24	20.57	31.54	-	1.53
S1R2	25	125	0.40	20.57	38.00	-	1.85
S1R3	35	125	0.56	20.57	37.97	-	1.85
S2R0	0	125	0.00	20.57	-	38.24	1.86
S2R1	15	125	0.24	20.57	-	40.39	1.96
S2R2	25	125	0.40	20.57	-	50.15	2.44
S2R3	35	125	0.56	20.57	-	45.75	2.22

Figure 5.23 shows graph of the strength gain of confined concrete f_{cc} / f_{co} versus corner radius ratio 2r/b. From the graph, it is clearly seen that the strength gain of the confined specimen is in direct proportion to the corner radius ratio.

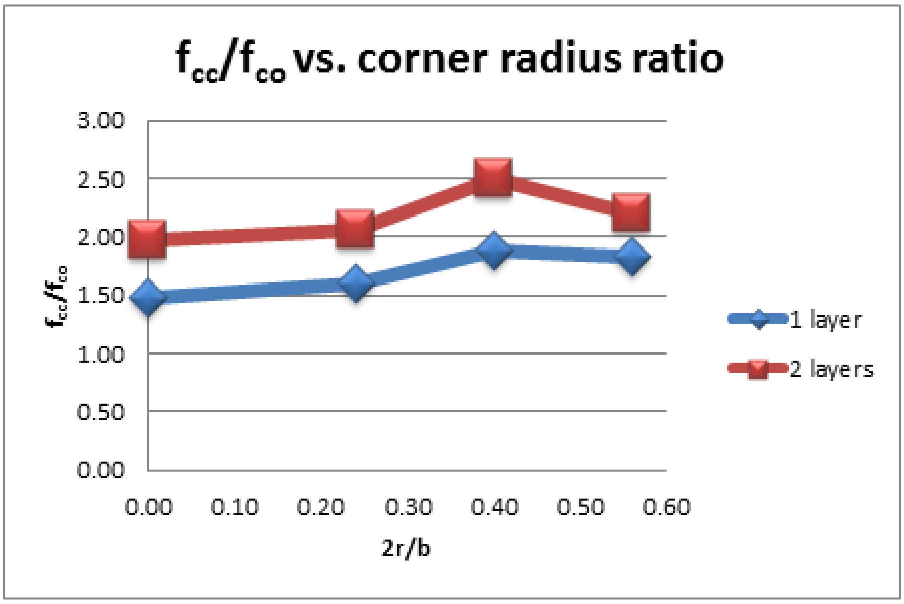


Figure 5.23: Strength gain of confined concrete vs. corner radius ratio

5.7 Failure Modes

Failure modes for unwrapped and wrapped column specimens are presented in this section. Cracks propagation, are visible before occurring the crushing of the unconfined RC member. Glass fibre wrapped specimens typically failed by a fracture of GFRP composite near the corner of the specimens due to the stress concentration in those regions. During the loading, clicking sounds used to heard, signifying the tearing of the FRP sheet and the cracking of the epoxy resin. The final failure occurred suddenly with an explosive sound.

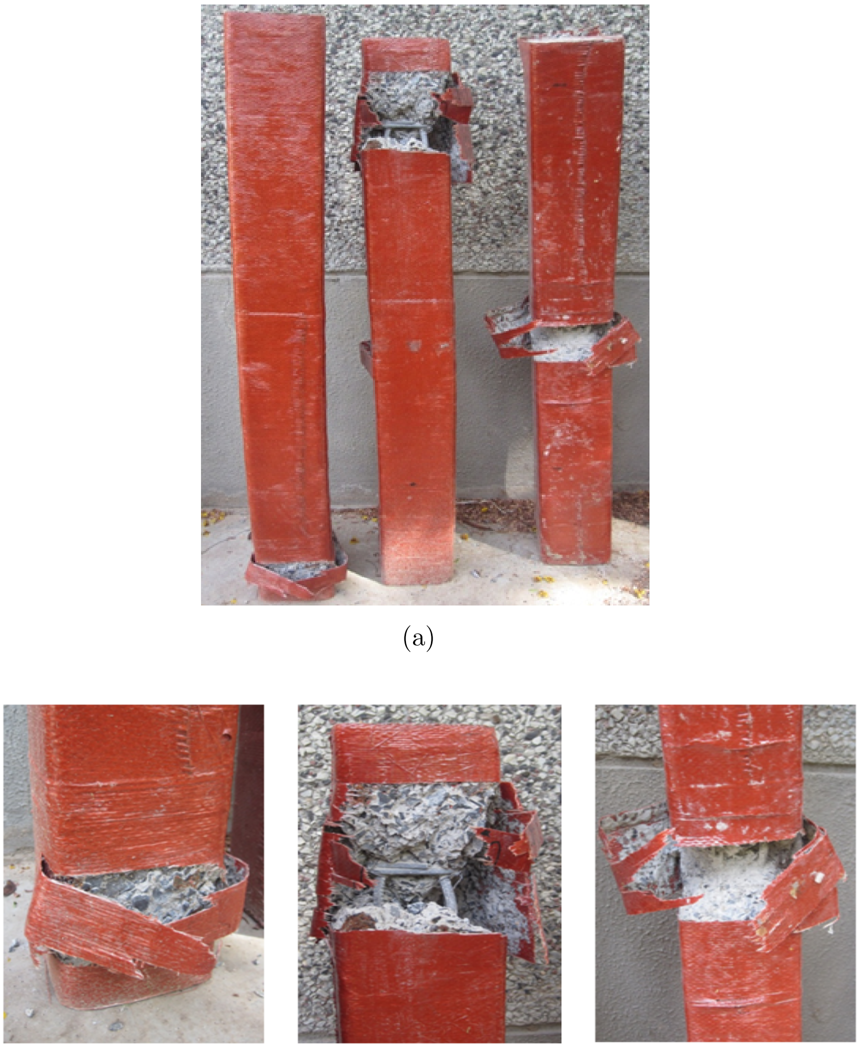
Figure 5.24 (a) shows the failure of S0R0 specimen from quarter height. Failure occurs between two ties, it means the confinement is lacking at the region therefore the concrete fails at that region. Figure 5.24 (b), Figure 5.24 (c) and Figure 5.24 (d) shows the failure of specimen by buckling of the longitudinal steel reinforcing bars.

(a)

(b) (c) (d)

Figure 5.24: Control specimen S0R0

Figure 5.25 shows failure of specimen S1R0, FRP fails at edges which shows that in sharp edges specimen stress concentration is very high at the edges. At the compressed side, near the mid height of the specimen, due to vertical shrinkage of the specimen are visible wrinkles in the FRP confined specimen. This wrinkles features the debonding of the FRP material from the concrete substrate in the end on this areas came the failure of the GFRP sheet.

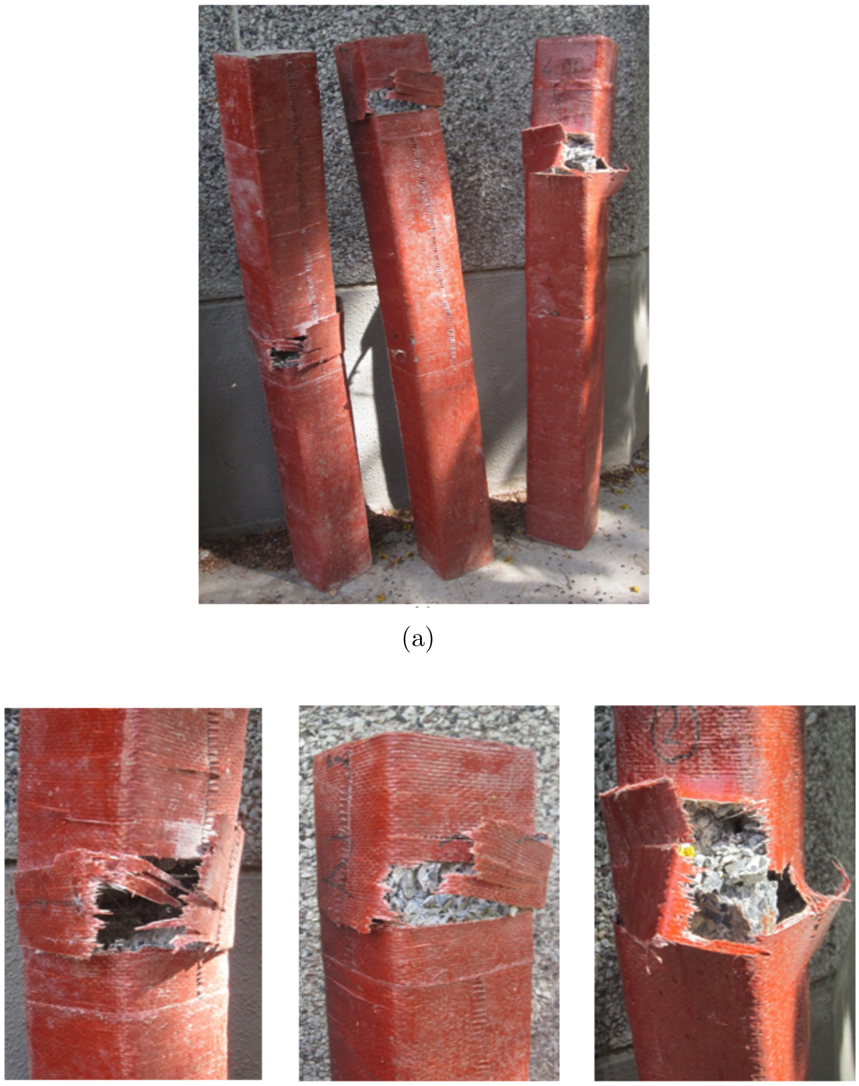


(a)

(b) (c) (d)

Figure 5.25: Specimens - S1R0

Figure 5.26 shows the failure of specimen S2R0, failure occurs at corner due to the stress concentration at the corner. Figure 5.26 (b), Figure 5.26 (c) and Figure 5.26 (d) shows evidently the rupture of FRP at the corner of specimen.

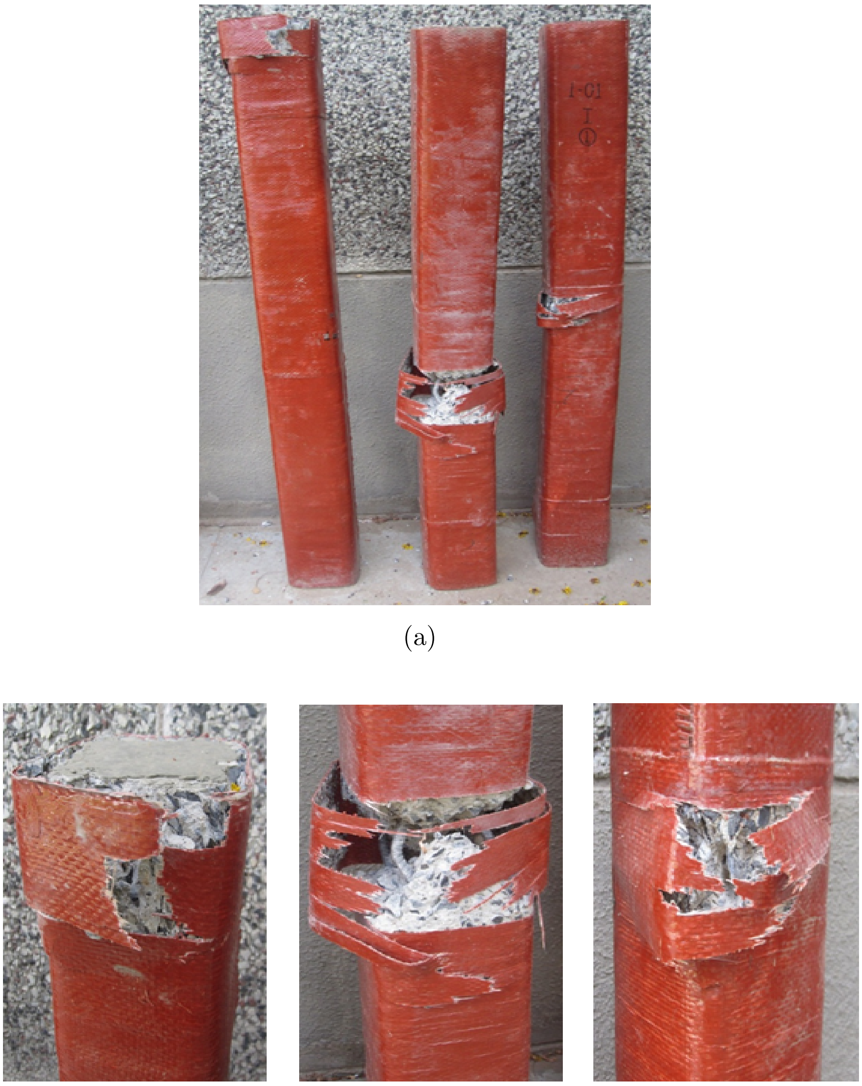


(a)

(b) (c) (d)

Figure 5.26: Specimen - S2R0

Figure 5.27 shows failure of specimen S1R1, from these three specimens one specimen fails due to premature failure which causes lesser ultimate failure load than other two specimens. Figure 5.27 (b) shows premature failure of column.

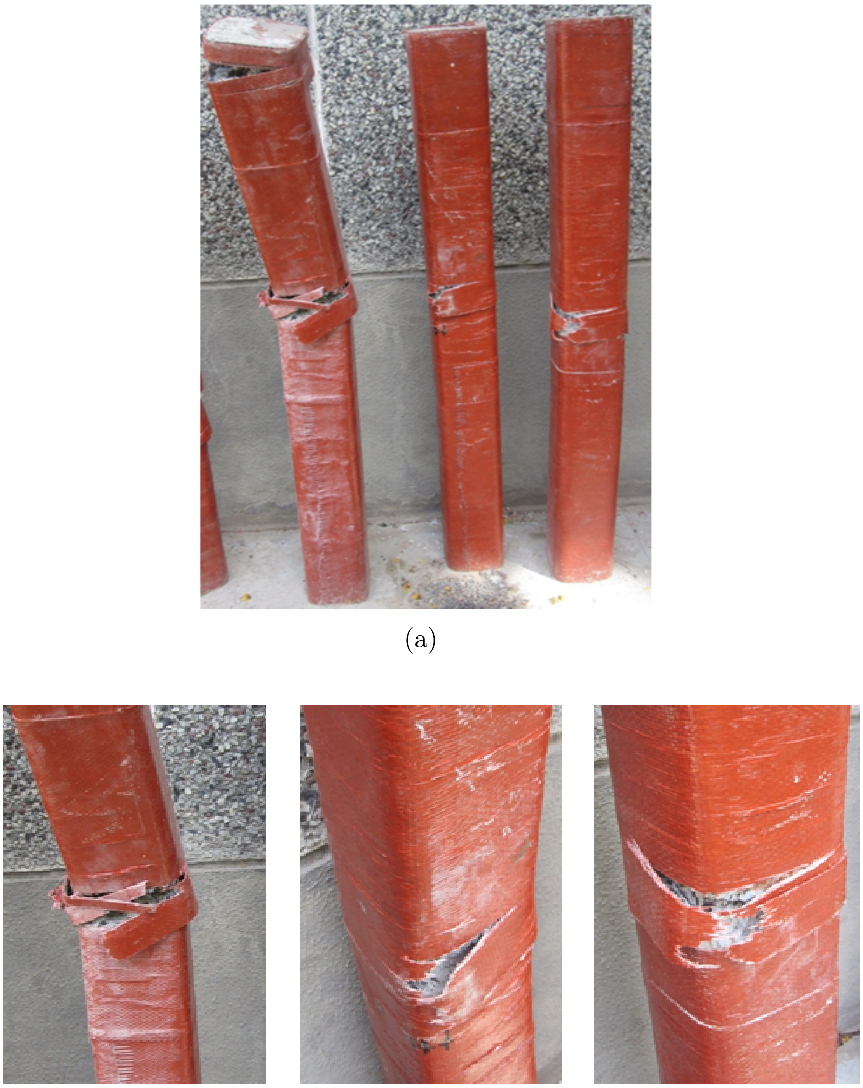


(a)

(b) (c) (d)

Figure 5.27: Specimen - S1R1

Figure 5.28 shows the failure of specimen S2R1, all the specimens fails from the center of column length. Figure 5.28 (b) shows bend form middle of column which occur due slenderness.

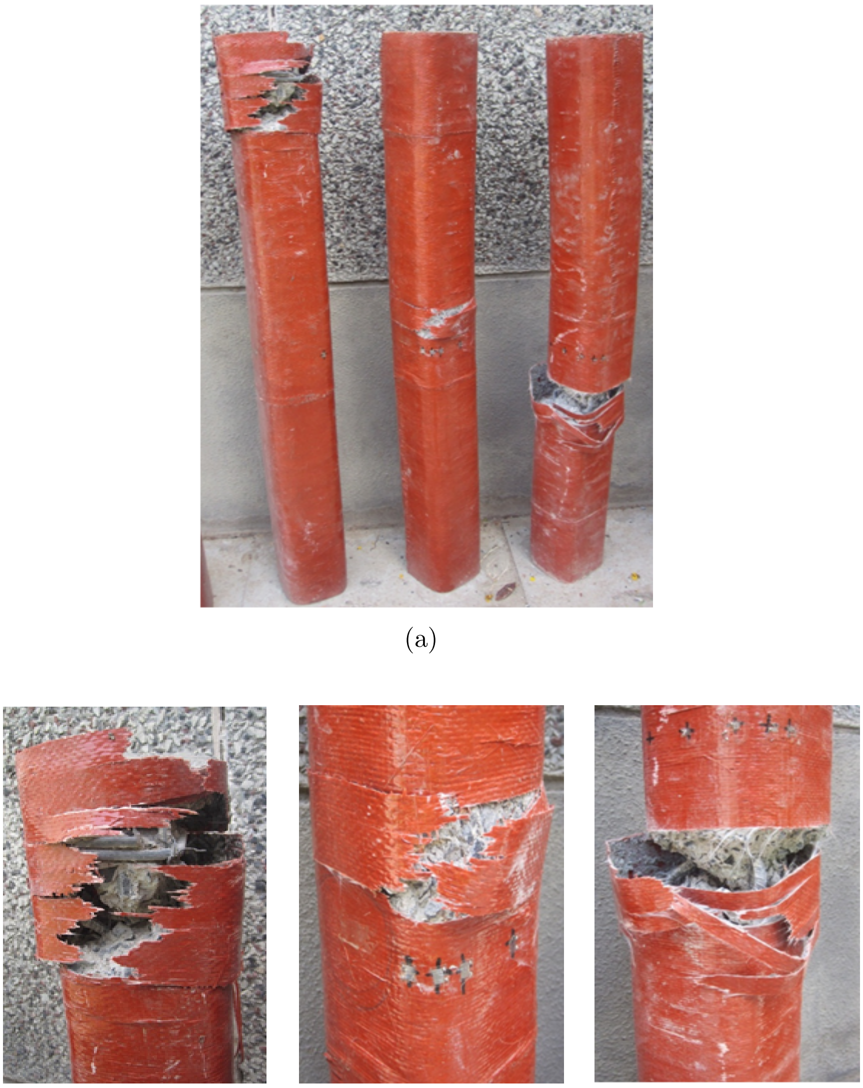


(a)

(b) (c) (d)

Figure 5.28: Specimen - S2R1

Figure 5.29 shows the failure of specimen S1R2, except one column other two are fails from the center of length. Figure 5.29 (b) shows the premature failure of the specimen. From Figure 5.29 (b), Figure 5.29 (c) and Figure 5.29 (d) shows that rupture zone shifting from corner to mid portion of sides.

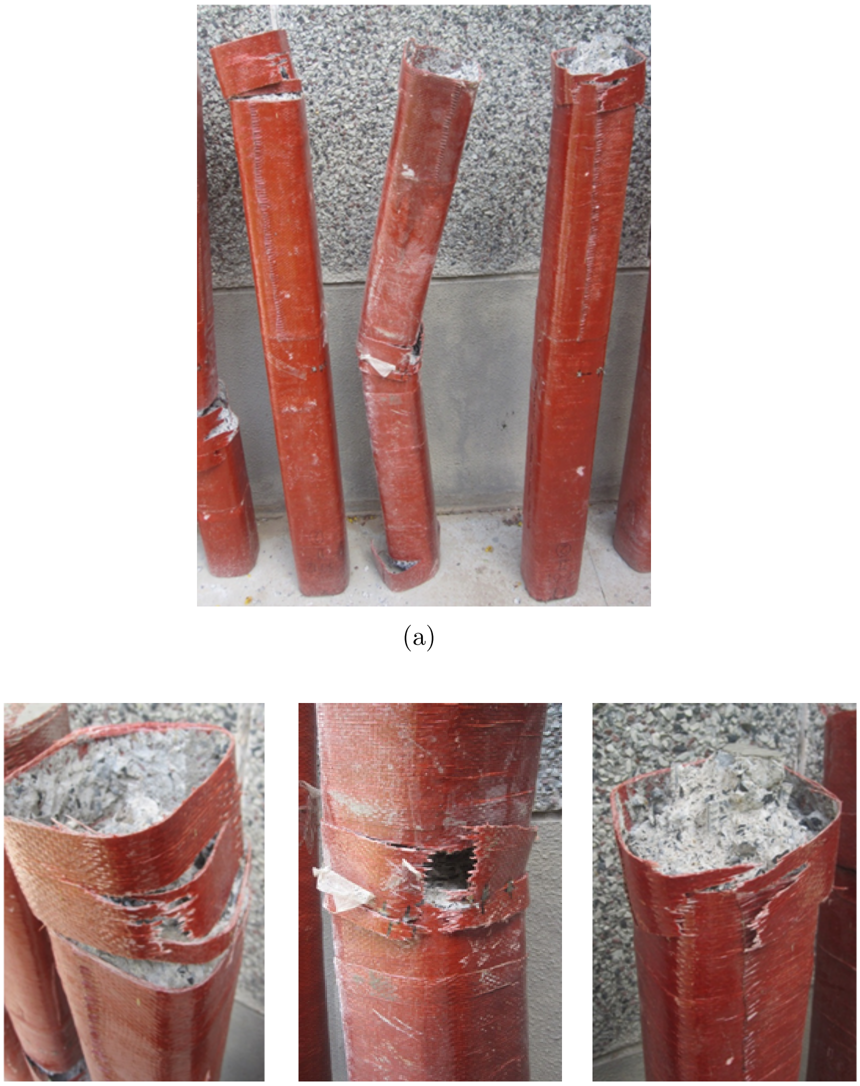


(a)

(b) (c) (d)

Figure 5.29: Specimen - S1R2

Figure 5.30 shows the failure of specimen S2R2, specimen fails from top due to premature failure. Figure 5.30 (b) and Figure 5.30 (d) shows the premature failure of specimen and reinforcement bar can be easily seen in Figure 5.30 (d).

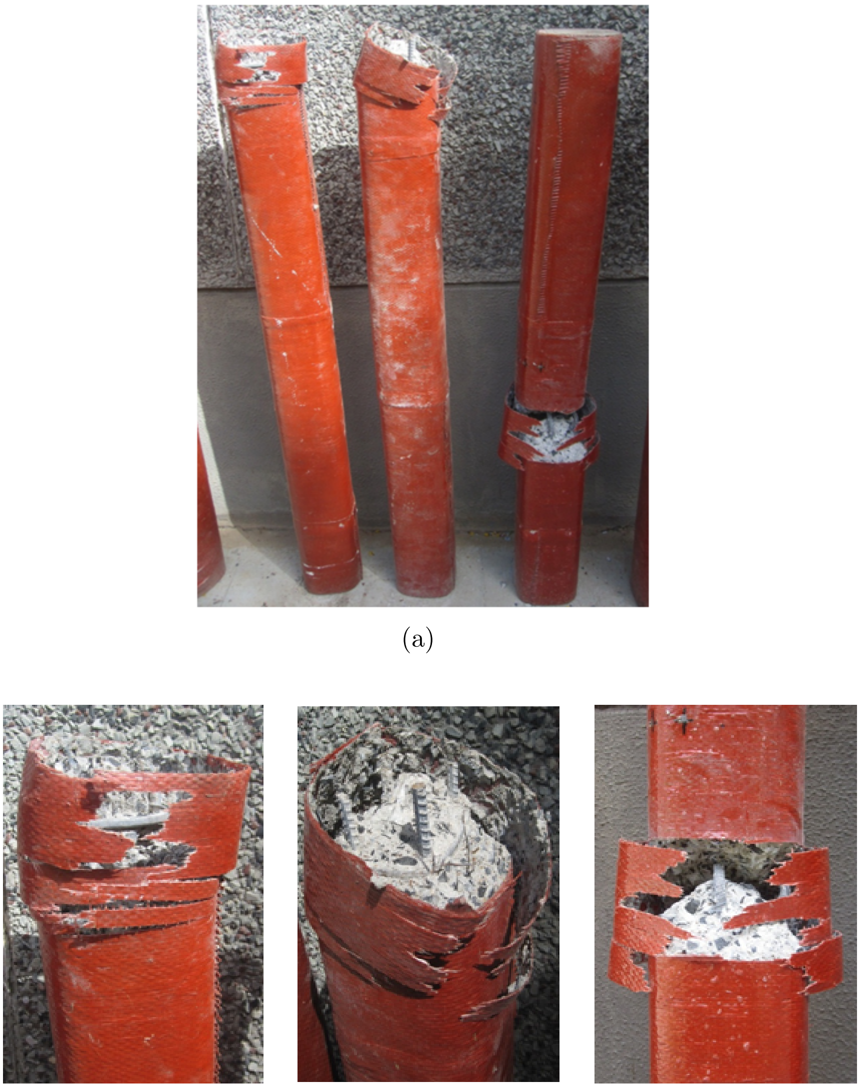


(a)

(b) (c) (d)

Figure 5.30: Specimen - S2R2

Figure 5.31 shows failure of specimen S1R3, in these columns also the premature failure observed. Figure 5.31 (d) shows rupture of FRP from the midpoint on side which shows ideal condition as the radius of specimen increased.



(a)

(b) (c) (d)

Figure 5.31: Specimen - S1R3

Figure 5.32 shows failure of specimen S2R3, specimen observed in this category also fails with premature failure. Figure 5.32 (b), Figure 5.32 (c) and Figure 5.32 (d) shows that rupture zone shifting from corner to mid face side.

(a)

(b)

(c)

(d)

Figure 5.32: Specimen - S2R3

5.8 Experimental and Analytical Results

Percentage variation in experimental result with analytical result for specimens are S0R0, S1R0, S2R0, S1R1, S2R1, S1R2, S2R2, S1R3 and S2R3 are 26.74 %, 120.53 %, 139.24 %, 122.05 %, 119.54 %, 148.92 %, 145.10 %, 134.66 % and 107.14 % respectively as shown in Table 5.22.

Table 5.22: Comparison for experimental results to analytical results

Notation	Analytical Results ACI code (kN)	Experimental Results (kN)	% Increment w.r.t Analytical results
S0R0	239.34	303.33	26.74
S1R0	202.54	446.67	120.53
S2R0	249.40	596.67	139.24
S1R1	219.17	486.67	122.05
S2R1	283.92	623.33	119.54
S1R2	230.32	573.33	148.92
S2R2	308.73	756.67	145.10
S1R3	235.80	553.33	134.66
S2R3	321.84	666.67	107.14

In Analytical calculation the formula ϕP_n for calculating axial load in confined condition, contains reduction factor, $\phi = 0.70$ that reduce the axial load carrying capacity. Therefore analytical results are conservative and showing less value than experimental results.

Chapter 6

Summary and Conclusion

6.1 Summary

A total of 27 RC columns are tested under axial loading. Three columns are unwrapped and have been designated as control specimens. Three columns each with corner radius equivalent to less than cover, equal to cover, greater than cover, are GFRP wrapped with one and two layers, respectively. The main purpose is to investigate the effect of corner radius on the effective confinement that is provided by GFRP sheet for RC columns. The test variables included the different corner radius and number of GFRP layers. The values of Ultimate failure load, displacement and lateral strain of columns are recorded. The test results indicate that corner radius is of great importance in relation to the level of confinement. Experimental test results are compared with value calculated from the IS 456: 2000, ACI 318M - 08 and ACI 440.2R - 08 code provisions.

6.2 Conclusions

Based on the analysis of experimental results and the performed analytical verification, the following conclusions can be drawn:

- The experimental results clearly demonstrate that GFRP wrapping can enhance the structural performance of RC columns under axial loading, in terms of both maximum strength and strain.

- Amongst all retrofitting techniques wrapping technique increasing axial strength by providing addition confinement without increasing the size.

- Percentage increment in ultimate failure load is ranging from 8.10 % to 149.45 % for all wrapped columns as compared to that of control columns.

- Ultimate load carrying capacity of specimens S1R0, S2R0, S1R1, S2R1, S1R2, S2R2, S1R3 and S2R3 is increased by 47.25 %, 96.70 %, 60.44 %, 130.77 %, 89.01 %, 149.45 %, 82.42 % and 119.78 %, respectively compared to specimen S0R0.

- The strength gain of confined concrete columns, $f_{cc}/\ f_{co}$, is in direct proportion to the corner radius ratio except in case 35 mm corner radius.

- Increasing the number of GFRP layers increases the axial compressive strengths of specimens, but the strength increase is not in linear relation with the number of GFRP layers.

- The specimen having corner radius of 25 mm performed best compare to corner radius of 0 mm, 15 mm and 35 mm.

- GFRP wrapped column goes under higher axial displacement in order to gain higher compressive strength over control column.

- Lateral strain is more at the mid side of specimen and then reduces at starting of curvature to center of curvature.

- The axial strength and displacement of specimens are increases with increase in number of GFRP layers.

- The final failure of GFRP wrapped specimen occurred suddenly with an explosive sound.
- From the failure of specimen it is clearly shown that the rupture of GFRP sheet transfers from edges (zone 1) to mid of side face (zone 2) of specimen.

6.3 Future Scope

The present study is limited to effect of corner radius and confinement layers on behaviour of RC column under axial compressive load. The study can be extended to include following aspects.

- Experimental work can be extended further by selecting different wrapping patterns of GFRP.
- Similar study can be carried out on column using different wrapping material and different loading condition.
- Comparative performance of different material like GFRP, CFRP etc. can be studied.
- Experimental work also can be done on rectangular column with different aspect ratios.

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Appendix A

Readings in Tabular form

This appendix A includes all readings of 27 columns individually: axial load, displacement, axial stress, axial strain and lateral strain for columns S0R0, S1R0, S2R0, S1R1, S2R1, S1R2, S2R2, S1R3 and S2R3, respectively.

Table A.1: Displacement of specimen S0R0

Specimen 1		Specimen 2		Specimen 3	
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	0	0.00	0	0.00
10	0.01	10	0.01	10	0.02
20	0.03	20	0.04	20	0.06
30	0.05	30	0.05	30	0.08
40	0.06	40	0.06	40	0.10
50	0.08	50	0.07	50	0.11
60	0.10	60	0.09	60	0.13
70	0.12	70	0.13	70	0.16
80	0.14	80	0.16	80	0.18
90	0.16	90	0.19	90	0.21
100	0.17	100	0.21	100	0.25
110	0.20	110	0.23	110	0.26
120	0.23	120	0.26	120	0.28
130	0.25	130	0.27	130	0.31
140	0.26	140	0.27	140	0.35
150	0.27	150	0.29	150	0.37
160	0.30	160	0.31	160	0.40
170	0.31	170	0.31	170	0.44
180	0.33	180	0.31	180	0.47
190	0.36	190	0.33	190	0.48
200	0.37	200	0.34	200	0.50
210	0.38	210	0.36	210	0.53
220	0.40	220	0.37	220	0.57
230	0.43	230	0.39	230	0.61
240	0.45	240	0.40	240	0.64
250	0.47	250	0.41	250	0.67
260	0.50	260	0.44	260	0.69
270	0.52	270	0.50	270	0.72
280	0.56	280	0.52	280	0.75
290	0.58	290	0.54	290	0.78
300	0.60	300	0.61		
310	0.63	310	0.82		

Table A.2: Displacement of specimen S1R0

Specimen 1			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	320	0.47
10	0.04	330	0.52
20	0.04	340	0.60
30	0.04	350	0.65
40	0.04	360	0.75
50	0.04	**370**	0.82
60	0.04	380	0.92
70	0.04	390	1.02
80	0.04	400	1.10
90	0.04	410	1.20
100	0.05	420	1.73
110	0.05	410	1.49
120	0.05	400	1.92
130	0.06	410	1.74
140	0.07	420	2.16
150	0.08	430	2.34
160	0.09	430	3.46
170	0.10	440	4.11
180	0.11	450	6.24
190	0.13	440	7.50
200	0.13	430	7.60
210	0.15	420	7.72
220	0.16	420	7.88
230	0.18	430	7.96
240	0.20	440	8.08
250	0.21	450	8.26
260	0.23	430	9.28
270	0.26	440	9.36
280	0.29	450	9.67
290	0.32	460	9.87
300	0.37	440	12.28
310	0.41		

Specimen 2			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	300	1.42
10	0.11	310	1.50
20	0.12	320	1.57
30	0.16	330	1.64
40	0.20	340	1.71
50	0.22	350	1.78
60	0.25	360	1.87
70	0.28	370	2.01
80	0.31	380	2.11
90	0.35	**390**	2.33
100	0.38	400	2.75
110	0.42	390	3.42
120	0.46	380	3.49
130	0.50	370	3.61
140	0.54	380	3.68
150	0.60	390	3.76
160	0.64	400	3.95
170	0.69	410	4.85
180	0.74	420	6.48
190	0.80	410	6.65
200	0.86	400	6.76
210	0.91	410	6.87
220	0.96	420	7.09
230	1.01	400	8.33
240	1.07	410	8.37
250	1.12	420	8.51
260	1.18	430	8.70
270	1.24	440	9.67
280	1.31	440	13.66
290	1.36		

Specimen 3			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	260	0.74
10	0.04	270	0.76
20	0.14	280	0.78
30	0.23	290	0.80
40	0.27	300	0.83
50	0.29	310	0.85
60	0.33	320	0.88
70	0.36	330	0.90
80	0.40	**340**	0.94
90	0.42	350	0.97
100	0.44	360	1.03
110	0.46	370	1.10
120	0.47	380	1.17
130	0.49	390	1.25
140	0.51	400	1.31
150	0.53	410	1.40
160	0.54	420	2.94
170	0.57	430	3.51
180	0.58	420	4.04
190	0.61	410	4.29
200	0.64	420	5.91
210	0.65	430	6.93
220	0.67	440	7.79
230	0.68	430	8.40
240	0.69	420	9.01
250	0.72	430	10.95

Table A.3: Displacement of specimen S2R0

Specimen 1					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	1.56	580	9.35
10	0.04	370	1.63	570	9.44
20	0.09	380	1.69	560	9.66
30	0.17	390	1.75	550	9.74
40	0.19	400	1.84	560	9.83
50	0.20	410	1.92	570	9.98
60	0.21	420	2.05	580	10.11
70	0.24	430	2.15	590	10.31
80	0.26	440	2.23	580	11.47
90	0.30	450	2.31	570	11.46
100	0.33	460	2.39	560	11.69
110	0.36	470	2.48	550	11.86
120	0.39	480	2.54	560	11.95
130	0.42	490	2.80	570	12.29
140	0.45	500	2.89	580	12.47
150	0.48	510	3.08	590	12.69
160	0.53	520	3.40		
170	0.54	530	3.73		
180	0.58	540	4.09		
190	0.62	550	4.27		
200	0.67	560	5.02		
210	0.70	570	5.95		
220	0.74	560	6.11		
230	0.78	550	5.19		
240	0.83	540	6.34		
250	0.87	550	6.54		
260	0.92	560	6.69		
270	0.96	570	6.93		
280	1.02	580	7.27		
290	1.12	570	7.41		
300	1.14	560	7.65		
310	1.19	550	7.77		
320	1.26	560	7.94		
330	1.33	570	8.08		
340	1.41	580	8.39		
350	1.50	590	9.17		

Specimen 2					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.0	360	0.7	560	7.8
10	0.0	370	0.7	570	8.3
20	0.0	380	0.8	560	8.6
30	0.0	390	0.8	550	8.8
40	0.0	400	0.9		
50	0.1	410	0.9		
60	0.1	420	1.0		
70	0.1	430	1.1		
80	0.1	440	1.2		
90	0.1	450	1.2		
100	0.1	460	1.3		
110	0.1	470	1.4		
120	0.2	480	1.7		
130	0.2	490	1.9		
140	0.2	500	2.0		
150	0.2	510	2.2		
160	0.2	520	2.5		
170	0.2	530	2.9		
180	0.2	540	3.2		
190	0.2	550	3.9		
200	0.2	540	4.3		
210	0.3	530	4.4		
220	0.3	520	4.5		
230	0.3	530	4.7		
240	0.3	540	4.8		
250	0.3	550	4.9		
260	0.3	560	5.5		
270	0.4	550	5.7		
280	0.4	540	5.8		
290	0.4	530	5.9		
300	0.5	540	6.0		
310	0.5	550	6.1		
320	0.5	560	6.3		
330	0.6	550	7.5		
340	0.6	540	7.6		
350	0.6	550	7.7		

Specimen 3					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	1.38	600	10.99
10	0.01	370	1.45	610	11.19
20	0.01	380	1.48	620	11.33
30	0.01	390	1.52	630	11.53
40	0.05	400	1.58	620	12.29
50	0.09	410	1.69	610	12.38
60	0.15	420	1.74	620	12.62
70	0.18	430	1.80	630	12.92
80	0.22	440	1.86		
90	0.25	450	1.92		
100	0.29	460	2.13		
110	0.34	470	2.18		
120	0.37	480	2.27		
130	0.41	**490**	2.39		
140	0.44	500	2.57		
150	0.49	510	2.75		
160	0.54	520	2.95		
170	0.58	530	3.06		
180	0.63	540	3.31		
190	0.66	550	3.50		
200	0.72	560	3.96		
210	0.79	570	4.25		
220	0.85	580	4.59		
230	0.88	590	5.15		
240	0.92	580	5.65		
250	0.97	590	5.81		
260	1.01	600	5.97		
270	1.05	610	7.03		
280	1.10	620	8.69		
290	1.14	610	9.02		
300	1.18	600	9.15		
310	1.20	610	9.39		
320	1.22	620	9.67		
330	1.29	630	10.16		
340	1.30	620	10.74		
350	1.35	610	10.85		

Table A.4: Displacement of specimen S1R1

Specimen 1			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	2.16
10	0.00	370	2.32
20	0.01	380	2.52
30	0.04	**390**	2.72
40	0.07	400	3.03
50	0.07	410	3.33
60	0.09	420	3.90
70	0.12	430	4.31
80	0.17	440	4.74
90	0.21	450	5.35
100	0.30	460	6.33
110	0.33	450	6.42
120	0.37	440	6.42
130	0.42	430	6.50
140	0.47	440	6.57
150	0.51	450	6.65
160	0.55	460	6.84
170	0.60	470	7.09
180	0.64	480	8.13
190	0.66	470	8.37
200	0.71	460	8.54
210	0.75	450	8.58
220	0.79	460	8.68
230	0.84	470	8.78
240	0.90	480	8.93
250	0.96	490	9.19
260	1.02		
270	1.09		
280	1.18		
290	1.27		
300	1.35		
310	1.48		
320	1.70		
330	1.80		
340	1.89		
350	2.01		

Specimen 2			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	2.15
10	0.01	370	2.36
20	0.03	380	2.53
30	0.05	390	2.66
40	0.10	**400**	2.76
50	0.11	410	2.90
60	0.16	420	3.02
70	0.22	430	3.36
80	0.26	440	3.44
90	0.31	450	3.58
100	0.36	440	3.89
110	0.39	430	3.93
120	0.41	440	4.17
130	0.43	450	4.81
140	0.42	460	5.00
150	0.42	450	5.92
160	0.46		
170	0.49		
180	0.52		
190	0.54		
200	0.56		
210	0.61		
220	0.64		
230	0.68		
240	0.72		
250	0.76		
260	0.80		
270	0.84		
280	0.91		
290	0.98		
300	1.05		
310	1.23		
320	1.40		
330	1.56		
340	1.70		
350	1.90		

Specimen 3			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	2.31
10	0.05	370	2.44
20	0.12	380	2.54
30	0.22	390	2.67
40	0.24	400	2.80
50	0.32	410	2.92
60	0.35	420	3.06
70	0.45	430	3.21
80	0.53	440	3.34
90	0.59	**450**	3.70
100	0.65	460	3.99
110	0.69	470	4.19
120	0.74	480	4.55
130	0.78	490	4.96
140	0.81	500	5.90
150	0.85	490	5.96
160	0.89	480	6.16
170	0.94	470	6.22
180	0.98	480	6.34
190	1.05	490	6.45
200	1.10	500	6.60
210	1.16	510	6.89
220	1.23		
230	1.30		
240	1.35		
250	1.42		
260	1.48		
270	1.59		
280	1.65		
290	1.70		
300	1.78		
310	1.86		
320	1.94		
330	2.03		
340	2.11		
350	2.21		

Table A.5: Displacement of specimen S2R1

Specimen 1			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	5.18
10	0.20	**370**	5.45
20	0.38	380	5.68
30	0.49	390	5.86
40	0.58	400	6.09
50	0.63	410	6.23
60	0.71	420	6.43
70	0.86	430	6.53
80	0.93	440	6.65
90	1.01	450	6.82
100	1.13	440	6.82
110	1.24	430	6.82
120	1.34	440	6.87
130	1.46	450	6.87
140	1.54	460	6.92
150	1.63	470	6.93
160	1.78	450	6.93
170	1.88	440	6.93
180	1.96		
190	2.04		
200	2.19		
210	2.29		
220	2.38		
230	2.53		
240	2.67		
250	2.87		
260	3.09		
270	3.30		
280	3.47		
290	3.61		
300	3.71		
310	4.00		
320	4.17		
330	4.27		
340	4.64		
350	4.82		

Specimen 2					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	1.24	680	10.15
10	0.00	370	1.33	690	10.43
20	0.02	380	1.38	680	10.93
30	0.06	390	1.45	670	11.03
40	0.08	400	1.54	680	11.16
50	0.10	410	1.61	690	11.29
60	0.13	420	1.73	700	11.79
70	0.15	430	1.84	710	12.50
80	0.17	440	1.92	720	12.85
90	0.19	450	2.02	730	13.43
100	0.23	460	2.17	720	13.61
110	0.25	470	2.29	710	13.70
120	0.28	480	2.42	700	13.79
130	0.31	490	2.58	690	13.88
140	0.35	500	2.79	700	14.05
150	0.37	510	2.99	710	14.21
160	0.41	520	3.11	720	14.47
170	0.45	530	3.23	730	14.72
180	0.48	540	3.43		
190	0.50	550	3.64		
200	0.54	560	4.00		
210	0.57	**570**	4.45		
220	0.61	580	4.83		
230	0.64	590	5.01		
240	0.67	600	5.47		
250	0.70	610	5.95		
260	0.74	620	6.71		
270	0.79	610	6.81		
280	0.84	600	6.90		
290	0.88	610	7.04		
300	0.92	620	7.16		
310	0.97	630	7.26		
320	1.02	640	7.38		
330	1.08	650	7.87		
340	1.11	660	9.08		
350	1.17	670	9.61		

Specimen 3					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	1.27	600	8.85
10	0.08	370	1.34	610	8.99
20	0.16	380	1.40	620	9.05
30	0.20	390	1.48	630	9.15
40	0.22	400	1.57	640	9.33
50	0.24	410	1.63	650	9.56
60	0.26	420	1.74	640	9.69
70	0.28	430	1.84	630	9.72
80	0.31	440	1.93	620	9.78
90	0.34	450	2.04	610	9.79
100	0.36	460	2.29	620	9.92
110	0.38	470	2.44	630	10.02
120	0.41	480	2.60	640	10.11
130	0.43	490	2.69	650	10.34
140	0.44	500	2.96	660	10.65
150	0.46	510	3.18	650	10.74
160	0.48	520	3.45	660	10.80
170	0.50	530	3.81	670	10.99
180	0.52	**540**	4.16	660	11.22
190	0.55	550	4.31	650	11.34
200	0.58	560	4.47		
210	0.61	570	4.80		
220	0.64	580	5.15		
230	0.67	590	5.42		
240	0.70	600	5.82		
250	0.73	610	6.83		
260	0.78	620	7.31		
270	0.81	610	7.46		
280	0.85	600	7.51		
290	0.89	610	7.77		
300	0.94	620	7.94		
310	0.98	630	8.22		
320	1.04	640	8.59		
330	1.09	630	8.67		
340	1.15	620	8.72		
350	1.20	610	8.75		

Table A.6: Displacement of specimen S1R2

Specimen 1					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	0.64	620	5.30
10	0.01	370	0.66	610	5.33
20	0.02	380	0.69	600	5.37
30	0.03	390	0.71	610	5.45
40	0.03	400	0.74	620	5.51
50	0.04	410	0.76	630	5.64
60	0.06	420	0.79	610	6.07
70	0.08	430	0.81	600	6.27
80	0.08	440	0.83		
90	0.09	450	0.84		
100	0.10	460	0.86		
110	0.11	470	0.88		
120	0.13	480	0.91		
130	0.16	490	0.94		
140	0.18	500	0.96		
150	0.19	510	0.98		
160	0.20	**520**	1.01		
170	0.21	530	1.04		
180	0.22	540	1.37		
190	0.24	550	1.62		
200	0.26	560	2.13		
210	0.28	550	2.63		
220	0.30	540	2.67		
230	0.32	530	2.73		
240	0.34	520	2.74		
250	0.36	530	2.81		
260	0.39	540	2.84		
270	0.41	550	2.89		
280	0.43	560	2.98		
290	0.46	570	3.10		
300	0.49	580	3.25		
310	0.51	590	3.51		
320	0.53	600	3.90		
330	0.55	610	4.35		
340	0.58	620	4.69		
350	0.62	630	4.96		

Specimen 2			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	3.84
10	0.03	370	4.10
20	0.05	380	4.42
30	0.07	390	4.87
40	0.11	400	5.17
50	0.13	410	5.80
60	0.17	420	6.24
70	0.21	430	6.70
80	0.27	**440**	7.43
90	0.33	450	8.01
100	0.40	460	8.49
110	0.46	470	9.09
120	0.52	480	9.41
130	0.60	490	9.97
140	0.69	500	10.62
150	0.76	510	11.09
160	0.89	520	11.29
170	0.97	530	11.70
180	1.10	540	12.07
190	1.27		
200	1.40		
210	1.54		
220	1.63		
230	1.77		
240	1.90		
250	2.03		
260	2.18		
270	2.30		
280	2.46		
290	2.60		
300	2.75		
310	3.00		
320	3.14		
330	3.32		
340	3.48		
350	3.64		

Specimen 3			
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	2.07
10	0.04	370	2.27
20	0.07	380	2.40
30	0.12	390	2.58
40	0.14	400	2.77
50	0.14	410	2.90
60	0.15	420	3.14
70	0.18	430	3.32
80	0.21	440	3.89
90	0.25	450	4.31
100	0.31	460	4.56
110	0.36	470	5.12
120	0.41	**480**	5.57
130	0.45	490	6.12
140	0.50	500	6.82
150	0.57	510	8.01
160	0.62	520	9.05
170	0.67	530	9.49
180	0.72	540	9.98
190	0.76	550	11.28
200	0.82	540	11.42
210	0.86	530	11.47
220	0.90	520	11.51
230	0.95	530	11.66
240	1.00	540	11.81
250	1.05	550	12.07
260	1.11		
270	1.17		
280	1.28		
290	1.34		
300	1.40		
310	1.48		
320	1.57		
330	1.66		
340	1.78		
350	1.92		

Table A.7: Displacement of specimen S2R2

Specimen 1					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	360	2.10	700	12.95
10	0.00	370	2.16	710	13.28
20	0.00	380	2.26	720	13.71
30	0.01	390	2.33	730	14.00
40	0.01	400	2.55	740	14.55
50	0.03	410	2.74	750	16.25
60	0.05	420	2.89	760	17.13
70	0.08	430	3.07	750	17.52
80	0.10	440	3.11	740	17.66
90	0.13	450	3.19	730	17.84
100	0.16	460	3.24	720	17.98
110	0.20	470	3.37	710	18.24
120	0.23	480	3.51	700	18.26
130	0.27	490	3.62	710	18.35
140	0.31	500	3.91	720	18.62
150	0.35	510	4.13	730	18.64
160	0.40	520	4.34	740	18.81
170	0.42	530	4.74	750	18.96
180	0.47	540	4.88	760	19.13
190	0.51	550	5.18	770	19.42
200	0.59	560	5.58	780	19.83
210	0.66	570	5.94	790	20.66
220	0.70	580	5.99	800	21.38
230	0.77	590	6.23		
240	0.84	600	6.62		
250	0.90	610	7.22		
260	1.00	620	7.58		
270	1.06	630	7.93		
280	1.16	640	8.19		
290	1.23	650	8.70		
300	1.33	**660**	9.47		
310	1.45	670	10.23		
320	1.56	680	10.42		
330	1.67	690	10.62		
340	1.75	700	11.48		
350	1.83	710	12.70		

Specimen 2					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	260	1.30	520	4.09
10	0.08	270	1.37	530	4.26
20	0.19	280	1.43	540	4.48
30	0.33	290	1.50	550	4.77
40	0.42	300	1.58	560	5.07
50	0.51	310	1.65	570	5.26
60	0.57	320	1.70	580	5.45
70	0.61	330	1.77	590	5.78
80	0.66	340	1.80	**600**	6.46
90	0.68	350	1.87	610	6.52
100	0.70	360	1.97	620	6.56
110	0.72	370	2.04	630	6.77
120	0.75	380	2.14	640	7.23
130	0.79	390	2.22	650	7.88
140	0.82	400	2.33	660	8.15
150	0.84	410	2.42	670	8.69
160	0.87	420	2.53	680	8.91
170	0.91	430	2.62	690	9.23
180	0.96	440	2.76	700	9.82
190	0.99	450	2.91	690	10.11
200	1.06	460	3.01	680	10.19
210	1.10	470	3.15	690	10.35
220	1.15	480	3.27	700	10.43
230	1.17	490	3.46	710	10.70
240	1.20	500	3.67	720	10.91
250	1.25	510	3.89	730	11.18

Specimen 3					
Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
0	0.00	290	1.04	580	6.22
10	0.00	300	1.10	590	6.52
20	0.01	310	1.17	600	6.84
30	0.01	320	1.24	610	7.10
40	0.01	330	1.29	620	7.41
50	0.01	340	1.36	630	7.76
60	0.02	350	1.45	640	8.08
70	0.02	360	1.56	650	8.55
80	0.03	370	1.66	660	8.84
90	0.06	380	1.72	670	9.17
100	0.10	390	1.78	680	9.32
110	0.13	400	1.86	690	9.52
120	0.16	410	1.96	700	9.92
130	0.19	420	2.05	690	9.96
140	0.23	430	2.19	680	9.99
150	0.29	440	2.38	670	10.03
160	0.33	450	2.60	680	10.18
170	0.38	460	2.85	690	10.25
180	0.42	470	2.98	700	10.35
190	0.46	480	3.21	710	10.59
200	0.52	490	3.48	720	11.01
210	0.55	500	3.66	730	11.11
220	0.61	510	3.92	740	11.39
230	0.67	520	4.22	730	11.42
240	0.72	530	4.51	720	11.44
250	0.77	**540**	4.76	710	11.53
260	0.84	550	5.05	700	14.22
270	0.94	560	5.41		
280	0.97	570	5.80		

Table A.8: Displacement of specimen S1R3

Specimen 1			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	310	0.99
10	0.02	320	1.05
20	0.04	330	1.09
30	0.06	340	1.16
40	0.07	350	1.21
50	0.08	360	1.25
60	0.09	370	1.29
70	0.11	380	1.36
80	0.12	390	1.41
90	0.14	400	1.47
100	0.16	410	1.52
110	0.19	420	1.60
120	0.21	430	1.66
130	0.23	440	1.75
140	0.26	450	1.87
150	0.29	460	2.15
160	0.33	470	2.33
170	0.37	480	2.51
180	0.42	490	2.81
190	0.46	500	2.89
200	0.50	510	2.92
210	0.55	520	2.91
220	0.60	530	2.87
230	0.64	540	2.57
240	0.67	550	3.28
250	0.72	**560**	3.52
260	0.76		
270	0.80		
280	0.86		
290	0.89		
300	0.93		

Specimen 2			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	330	0.77
10	0.02	340	0.81
20	0.04	350	0.86
30	0.05	360	0.92
40	0.06	370	0.98
50	0.07	380	1.06
60	0.09	390	1.15
70	0.12	400	1.24
80	0.14	410	1.36
90	0.16	420	1.47
100	0.17	430	1.68
110	0.19	440	1.81
120	0.21	450	1.90
130	0.23	460	1.97
140	0.26	470	2.18
150	0.28	480	2.33
160	0.30	490	2.66
170	0.32	500	2.75
180	0.34	510	2.83
190	0.37	**520**	2.94
200	0.39	530	3.01
210	0.42	540	3.14
220	0.44	550	3.29
230	0.47	560	3.39
240	0.49	570	3.53
250	0.51	580	3.87
260	0.54	590	4.01
270	0.57	600	4.35
280	0.61	590	4.52
290	0.65	580	4.74
300	0.67	570	5.07
310	0.70	580	5.48
320	0.73	590	6.58

Specimen 3			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	260	0.55
10	0.00	270	0.69
20	0.01	280	0.72
30	0.02	290	0.77
40	0.03	300	0.86
50	0.05	310	0.93
60	0.07	320	1.01
70	0.09	330	1.09
80	0.11	340	1.19
90	0.14	350	1.31
100	0.17	360	1.42
110	0.19	370	1.51
120	0.21	380	1.67
130	0.23	390	1.85
140	0.26	400	1.97
150	0.28	410	2.13
160	0.31	**420**	2.20
170	0.34	430	2.42
180	0.37	440	2.52
190	0.39	450	2.72
200	0.41	460	2.94
210	0.43	470	3.09
220	0.46	480	3.90
230	0.48	490	4.45
240	0.51	500	5.29
250	0.53		

Table A.9: Displacement of specimen S2R3

Specimen 1			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	350	1.43
10	0.02	360	1.52
20	0.02	370	1.62
30	0.08	380	1.71
40	0.10	390	1.81
50	0.11	400	1.95
60	0.15	410	2.11
70	0.19	420	2.30
80	0.25	430	2.47
90	0.30	440	2.60
100	0.36	450	2.85
110	0.41	460	3.20
120	0.46	470	3.34
130	0.48	480	3.62
140	0.50	490	3.90
150	0.53	500	4.18
160	0.56	510	4.42
170	0.60	520	4.84
180	0.61	530	5.10
190	0.66	540	5.31
200	0.67	550	5.61
210	0.68	560	5.87
220	0.69	570	6.08
230	0.73	580	6.71
240	0.75	590	6.82
250	0.79	600	7.26
260	0.84	610	7.53
270	0.88	620	7.87
280	0.91	630	8.47
290	0.94	640	8.68
300	1.01	650	9.08
310	1.07	660	9.80
320	1.15	670	10.32
330	1.24	680	10.76
340	1.32		

Specimen 2			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	380	2.58
10	0.08	390	2.70
20	0.20	400	2.83
30	0.26	410	3.00
40	0.29	420	3.12
50	0.33	430	3.22
60	0.37	440	3.35
70	0.41	450	3.53
80	0.48	460	3.75
90	0.52	470	3.91
100	0.59	480	3.97
110	0.64	490	4.17
120	0.69	500	4.44
130	0.74	510	4.77
140	0.79	520	4.98
150	0.86	530	5.22
160	0.92	540	5.59
170	0.95	550	5.85
180	1.02	560	6.25
190	1.05	570	6.68
200	1.13	580	7.01
210	1.19	590	7.69
220	1.24	600	8.09
230	1.31	610	8.40
240	1.37	620	9.03
250	1.46	630	9.61
260	1.55	640	10.04
270	1.63	650	11.70
280	1.69	660	12.04
290	1.76	670	12.41
300	1.86	680	13.14
310	1.92	670	13.56
320	2.00	660	13.60
330	2.02	650	13.64
340	2.11	660	13.85
350	2.23	670	14.42
360	2.34	680	16.59
370	2.47	670	17.64

Specimen 3			
Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0.00	360	2.83
10	0.04	370	2.98
20	0.13	380	3.08
30	0.23	390	3.24
40	0.27	400	3.51
50	0.33	410	3.89
60	0.38	420	4.09
70	0.45	430	4.32
80	0.52	440	4.59
90	0.58	450	4.98
100	0.66	460	5.40
110	0.71	470	6.00
120	0.77	480	6.45
130	0.84	490	6.86
140	0.88	500	7.44
150	0.94	510	8.01
160	1.01	520	8.60
170	1.08	530	9.13
180	1.13	540	10.19
190	1.19	550	10.58
200	1.28	560	11.34
210	1.34	570	11.97
220	1.39	580	12.30
230	1.46	590	13.22
240	1.54	600	14.18
250	1.62	590	14.40
260	1.70	580	14.43
270	1.80	590	14.73
280	1.90	600	14.89
290	1.98	610	15.49
300	2.08	620	15.98
310	2.18	630	16.46
320	2.30	620	17.17
330	2.43	610	17.36
340	2.56	620	17.52
350	2.67	630	17.70

Table A.10: Lateral strain of specimen S0R0

Load (kN)	Strain				Average strain	
	1				Mid	Corner
	Mid 1	Mid 2	Corner 1	Corner 2		
0	0.00000	0.00001	0.00000	-0.00001	0.00001	-0.00001
10	-0.00001	0.00022	-0.00005	0.00015	0.00011	0.00005
20	0.00000	0.00030	-0.00007	0.00024	0.00015	0.00009
30	0.00000	0.00032	-0.00007	0.00025	0.00016	0.00009
40	-0.00002	0.00031	-0.00008	0.00022	0.00015	0.00007
50	0.00001	0.00035	-0.00008	0.00026	0.00018	0.00009
60	0.00001	0.00038	-0.00009	0.00030	0.00020	0.00011
70	0.00006	0.00043	-0.00009	0.00035	0.00025	0.00013
80	0.00012	0.00046	-0.00010	0.00040	0.00029	0.00015
90	0.00019	0.00048	-0.00010	0.00044	0.00034	0.00017
100	0.00023	0.00052	-0.00010	0.00049	0.00038	0.00020
110	0.00025	0.00054	-0.00010	0.00052	0.00040	0.00021
120	0.00027	0.00055	-0.00010	0.00058	0.00041	0.00024
130	0.00029	0.00057	-0.00010	0.00063	0.00043	0.00027
140	0.00028	0.00059	-0.00009	0.00069	0.00044	0.00030
150	0.00029	0.00063	-0.00007	0.00077	0.00046	0.00035
160	0.00032	0.00066	-0.00004	0.00084	0.00049	0.00040
170	0.00034	0.00069	-0.00002	0.00089	0.00052	0.00044
180	0.00036	0.00074	0.00001	0.00096	0.00055	0.00049
190	0.00033	0.00077	0.00007	0.00104	0.00055	0.00056
200	0.00030	0.00081	0.00012	0.00112	0.00056	0.00062
210	0.00029	0.00085	0.00017	0.00116	0.00057	0.00067
220	0.00025	0.00083	0.00023	0.00125	0.00054	0.00074
230	0.00023	0.00096	0.00028	0.00136	0.00060	0.00082
240	0.00022	0.00111	0.00032	0.00149	0.00067	0.00091
250	0.00020	0.00186	0.00040	0.00154	0.00103	0.00097
260	0.00022	0.00222	0.00049	0.00164	0.00122	0.00107
270	0.00028	0.00234	0.00065	0.00167	0.00131	0.00116
280	0.00035	0.00245	0.00084	0.00165	0.00140	0.00125
290	0.00057	0.00264	0.00133	0.00159	0.00161	0.00146
300	0.00072	0.00294	0.00206	0.00152	0.00183	0.00179
310	0.00110	0.00595	0.00292	0.00141	0.00353	0.00217

Load (kN)	strain				Average strain	
	2				Mid	Corner
	Mid 1	Mid 2	Corner 1	Corner 2		
0	-0.00001	-0.00001	0.00000	0.00000	-0.00001	0.00000
10	-0.00001	0.00000	0.00000	0.00001	-0.00001	0.00001
20	-0.00001	0.00001	-0.00001	0.00002	0.00000	0.00001
30	0.00000	0.00001	0.00000	0.00002	0.00001	0.00001
40	0.00000	0.00001	0.00000	0.00001	0.00001	0.00001
50	0.00000	-0.00001	0.00000	0.00001	-0.00001	0.00001
60	0.00000	-0.00001	0.00000	0.00001	-0.00001	0.00001
70	0.00001	0.00000	0.00001	0.00002	0.00001	0.00002
80	0.00002	0.00001	0.00000	0.00003	0.00002	0.00002
90	0.00003	0.00002	0.00000	0.00003	0.00003	0.00002
100	0.00004	0.00003	0.00000	0.00003	0.00004	0.00002
110	0.00005	0.00003	0.00001	0.00004	0.00004	0.00003
120	0.00005	0.00003	0.00001	0.00004	0.00004	0.00003
130	0.00006	0.00004	0.00000	0.00005	0.00005	0.00003
140	0.00008	0.00005	0.00000	0.00006	0.00007	0.00003
150	0.00009	0.00006	0.00001	0.00006	0.00008	0.00004
160	0.00011	0.00006	0.00000	0.00007	0.00009	0.00004
170	0.00012	0.00005	0.00001	0.00008	0.00009	0.00005
180	0.00012	0.00006	0.00001	0.00008	0.00009	0.00005
190	0.00014	0.00006	0.00001	0.00009	0.00010	0.00005
200	0.00015	0.00006	0.00002	0.00011	0.00011	0.00007
210	0.00015	0.00006	0.00003	0.00011	0.00011	0.00007
220	0.00016	0.00008	0.00004	0.00012	0.00012	0.00008
230	0.00018	0.00010	0.00004	0.00014	0.00014	0.00009
240	0.00018	0.00011	0.00004	0.00015	0.00015	0.00010
250	0.00020	0.00012	0.00005	0.00018	0.00016	0.00012
260	0.00022	0.00015	0.00004	0.00022	0.00019	0.00013
270	0.00023	0.00016	-0.00001	0.00026	0.00020	0.00013
280	0.00025	0.00018	-0.00252	0.00032	0.00022	-0.00110
290	0.00025	0.00019	-0.00366	0.00035	0.00022	-0.00166
300	0.00027	0.00026	-0.00452	0.00041	0.00027	-0.00206
310	0.00028	0.00027	-0.00578	0.00052	0.00028	-0.00263

Load (kN)	Strain				Average strain	
	3				Mid	Corner
	Mid 1	Mid 2	Corner 1	Corner 2		
0	-0.00001	0.00001	0.00000	-0.00003	0.00000	-0.00002
10	-0.00001	0.00001	0.00000	-0.00003	0.00000	-0.00002
20	-0.00002	0.00000	-0.00001	-0.00004	-0.00001	-0.00003
30	-0.00002	0.00000	0.00000	-0.00005	-0.00001	-0.00003
40	-0.00002	0.00000	0.00000	-0.00005	-0.00001	-0.00003
50	-0.00002	-0.00001	0.00000	-0.00006	-0.00002	-0.00003
60	-0.00003	-0.00002	0.00000	-0.00007	-0.00003	-0.00004
70	-0.00005	-0.00005	0.00001	-0.00009	-0.00005	-0.00004
80	-0.00006	-0.00006	0.00000	-0.00009	-0.00006	-0.00005
90	-0.00006	-0.00007	0.00000	-0.00010	-0.00007	-0.00005
100	-0.00006	-0.00007	0.00000	-0.00010	-0.00007	-0.00005
110	-0.00009	-0.00012	0.00001	-0.00011	-0.00011	-0.00005
120	-0.00009	-0.00012	0.00001	-0.00010	-0.00011	-0.00005
130	-0.00008	-0.00012	0.00000	-0.00010	-0.00010	-0.00005
140	-0.00008	-0.00012	0.00000	-0.00009	-0.00010	-0.00005
150	-0.00008	-0.00012	0.00001	-0.00009	-0.00010	-0.00004
160	-0.00008	-0.00013	0.00000	-0.00009	-0.00011	-0.00005
170	-0.00008	-0.00013	0.00001	-0.00008	-0.00011	-0.00004
180	-0.00007	-0.00013	0.00001	-0.00007	-0.00010	-0.00003
190	-0.00007	-0.00013	0.00001	-0.00006	-0.00010	-0.00003
200	-0.00006	-0.00013	0.00002	-0.00004	-0.00010	-0.00001
210	-0.00006	-0.00013	0.00003	-0.00004	-0.00010	-0.00001
220	-0.00005	-0.00013	0.00004	-0.00003	-0.00009	0.00001
230	-0.00005	-0.00013	0.00004	-0.00001	-0.00009	0.00002
240	-0.00004	-0.00013	0.00004	0.00001	-0.00009	0.00003
250	-0.00003	-0.00013	0.00005	0.00004	-0.00008	0.00005
260	-0.00003	-0.00013	0.00004	0.00006	-0.00008	0.00005
270	-0.00002	-0.00013	-0.00001	0.00009	-0.00008	0.00004
280	0.00000	-0.00012	-0.00002	0.00015	-0.00006	0.00007
290	0.00002	-0.00011	-0.00006	0.00024	-0.00005	0.00009

Table A.11: Lateral strain of specimen S1R0

Load (kN)	Area	Stress N/mm^2	Strain				Average strain	
			1				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
0	15604	0.00	0.00000	-0.00001	-0.00003	-0.00001	-0.00001	-0.00002
10	15604	0.64	0.00000	0.00001	-0.00005	0.00000	0.00001	-0.00003
20	15604	1.28	-0.00001	0.00002	-0.00010	0.00001	0.00001	-0.00005
30	15604	1.92	0.00000	0.00003	-0.00012	0.00000	0.00002	-0.00006
40	15604	2.56	0.00001	0.00003	-0.00015	0.00000	0.00002	-0.00008
50	15604	3.20	0.00000	0.00003	-0.00019	0.00001	0.00002	-0.00009
60	15604	3.85	0.00000	0.00003	-0.00022	0.00000	0.00002	-0.00011
70	15604	4.49	0.00001	0.00003	-0.00024	0.00000	0.00002	-0.00012
80	15604	5.13	0.00000	0.00003	-0.00026	0.00001	0.00002	-0.00013
90	15604	5.77	0.00001	0.00003	-0.00028	0.00000	0.00002	-0.00014
100	15604	6.41	0.00000	0.00004	-0.00030	0.00001	0.00002	-0.00015
110	15604	7.05	0.00001	0.00004	-0.00032	0.00001	0.00003	-0.00016
120	15604	7.69	0.00001	0.00003	-0.00037	0.00001	0.00002	-0.00018
130	15604	8.33	0.00001	0.00003	-0.00038	0.00002	0.00002	-0.00018
140	15604	8.97	0.00001	0.00004	-0.00038	0.00000	0.00003	-0.00019
150	15604	9.61	0.00001	0.00004	-0.00040	0.00001	0.00003	-0.00020
160	15604	10.25	0.00001	0.00005	-0.00042	0.00002	0.00003	-0.00020
170	15604	10.89	0.00001	0.00006	-0.00042	0.00002	0.00004	-0.00020
180	15604	11.54	0.00002	0.00006	-0.00043	0.00002	0.00004	-0.00021
190	15604	12.18	0.00001	0.00008	-0.00044	0.00002	0.00005	-0.00021
200	15604	12.82	0.00002	0.00008	-0.00045	0.00002	0.00005	-0.00022
210	15604	13.46	0.00003	0.00009	-0.00045	0.00001	0.00006	-0.00022
220	15604	14.10	0.00002	0.00010	-0.00046	0.00001	0.00006	-0.00023
230	15604	14.74	0.00002	0.00009	-0.00047	0.00003	0.00006	-0.00022
240	15604	15.38	0.00002	0.00011	-0.00047	0.00003	0.00007	-0.00022
250	15604	16.02	0.00003	0.00011	-0.00047	0.00002	0.00007	-0.00023
260	15604	16.66	0.00003	0.00013	-0.00051	0.00003	0.00008	-0.00024
270	15604	17.30	0.00004	0.00013	-0.00055	0.00002	0.00009	-0.00027
280	15604	17.94	0.00003	0.00015	-0.00059	0.00004	0.00009	-0.00028
290	15604	18.58	0.00003	0.00017	-0.00061	0.00004	0.00010	-0.00029
300	15604	19.23	0.00004	0.00019	-0.00063	0.00005	0.00012	-0.00029
310	15604	19.87	0.00004	0.00022	-0.00064	0.00004	0.00013	-0.00030
320	15604	20.51	0.00005	0.00023	-0.00066	0.00004	0.00014	-0.00031
330	15604	21.15	0.00005	0.00026	-0.00066	0.00005	0.00016	-0.00031
340	15604	21.79	0.00006	0.00028	-0.00064	0.00005	0.00017	-0.00030
350	15604	22.43	0.00006	0.00031	-0.00063	0.00006	0.00019	-0.00029
360	15604	23.07	0.00005	0.00036	-0.00066	0.00008	0.00021	-0.00029
370	15604	23.71	0.00006	0.00040	-0.00066	0.00008	0.00023	-0.00029

Load (kN)	Area	Stress N/mm^2	Strain				Average strain	
			1				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
380	15604	24.35	0.00007	0.00046	-0.00064	0.00008	0.00027	-0.00028
390	15604	24.99	0.00008	0.00043	-0.00062	0.00010	0.00026	-0.00026
400	15604	25.63	0.00008	0.00046	-0.00055	0.00010	0.00027	-0.00023
410	15604	26.28	0.00010	0.00050	-0.00046	0.00010	0.00030	-0.00018
420	15604	26.92	0.00010	0.00054	-0.00024	0.00012	0.00032	-0.00006
410	15604	26.28	0.00010	0.00059	0.00000	0.00012	0.00035	0.00006
400	15604	25.63	0.00011	0.00046	0.00012	0.00011	0.00029	0.00012
410	15604	26.28	0.00011	0.00050	0.00027	0.00011	0.00031	0.00019
420	15604	26.92	0.00011	0.00055	0.00026	0.00011	0.00033	0.00019
430	15604	27.56	0.00010	0.00069	0.00032	0.00010	0.00040	0.00021
430	15604	27.56	0.00010	0.00080	0.00059	0.00009	0.00045	0.00034
440	15604	28.20	0.00010	0.00062	0.00009	0.00007	0.00036	0.00008
450	15604	28.84	0.00012	0.00166	-0.00092	0.00005	0.00089	-0.00044
440	15604	28.20	0.00012	0.00157	-0.00116	0.00005	0.00085	-0.00056
430	15604	27.56	0.00012	0.00152	-0.00143	0.00005	0.00082	-0.00069
420	15604	26.92	0.00012	0.00156	-0.00163	0.00006	0.00084	-0.00079
420	15604	26.92	0.00012	0.00167	-0.00144	0.00007	0.00090	-0.00069
430	15604	27.56	0.00013	0.00192	-0.00142	0.00006	0.00103	-0.00068
440	15604	28.20	0.00012	0.00244	-0.00148	0.00006	0.00128	-0.00071
450	15604	28.84	0.00015	0.00444	-0.00305	0.00005	0.00230	-0.00150
430	15604	27.56	0.00016	0.00452	-0.00303	0.00006	0.00234	-0.00149
440	15604	28.20	0.00016	0.00485	-0.00302	0.00006	0.00251	-0.00148
450	15604	28.84	0.00020	0.00549	-0.00275	0.00004	0.00285	-0.00136
460	15604	29.48	0.00030	0.00818	-0.00217	0.00004	0.00424	-0.00107
440	15604	28.20	0.00031	0.00822	-0.00211	0.00003	0.00427	-0.00104

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			2				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
0	15604	0.00	0.00000	0.00000	0.00002	-0.00004	0.00000	-0.00001
10	15604	0.64	-0.00001	0.00000	0.00002	0.00000	-0.00001	0.00001
20	15604	1.28	0.00000	0.00000	0.00004	0.00001	0.00000	0.00003
30	15604	1.92	0.00000	0.00000	0.00003	0.00002	0.00000	0.00003
40	15604	2.56	0.00000	0.00000	0.00003	0.00001	0.00000	0.00002
50	15604	3.20	0.00000	0.00000	0.00004	0.00001	0.00000	0.00003
60	15604	3.85	0.00000	-0.00001	0.00004	0.00001	-0.00001	0.00003
70	15604	4.49	0.00001	-0.00001	0.00005	0.00001	0.00000	0.00003
80	15604	5.13	0.00002	0.00000	0.00005	0.00002	0.00001	0.00004
90	15604	5.77	0.00003	0.00000	0.00005	0.00003	0.00002	0.00004
100	15604	6.41	0.00003	0.00001	0.00006	0.00004	0.00002	0.00005
110	15604	7.05	0.00004	0.00001	0.00006	0.00004	0.00003	0.00005
120	15604	7.69	0.00004	0.00001	0.00007	0.00005	0.00003	0.00006
130	15604	8.33	0.00004	0.00002	0.00008	0.00007	0.00003	0.00008
140	15604	8.97	0.00005	0.00002	0.00009	0.00008	0.00004	0.00009
150	15604	9.61	0.00006	0.00002	0.00009	0.00010	0.00004	0.00010
160	15604	10.25	0.00006	0.00003	0.00009	0.00012	0.00005	0.00011
170	15604	10.89	0.00007	0.00004	0.00010	0.00013	0.00006	0.00012
180	15604	11.54	0.00008	0.00004	0.00010	0.00015	0.00006	0.00013
190	15604	12.18	0.00009	0.00005	0.00011	0.00017	0.00007	0.00014
200	15604	12.82	0.00011	0.00006	0.00012	0.00018	0.00009	0.00015
210	15604	13.46	0.00012	0.00006	0.00013	0.00019	0.00009	0.00016
220	15604	14.10	0.00013	0.00008	0.00013	0.00021	0.00011	0.00017
230	15604	14.74	0.00016	0.00009	0.00014	0.00023	0.00013	0.00019
240	15604	15.38	0.00018	0.00011	0.00015	0.00024	0.00015	0.00020
250	15604	16.02	0.00020	0.00012	0.00017	0.00026	0.00016	0.00022
260	15604	16.66	0.00023	0.00014	0.00017	0.00028	0.00019	0.00023
270	15604	17.30	0.00026	0.00017	0.00018	0.00029	0.00022	0.00024
280	15604	17.94	0.00032	0.00021	0.00019	0.00032	0.00027	0.00026
290	15604	18.58	0.00038	0.00026	0.00020	0.00034	0.00032	0.00027
300	15604	19.23	0.00046	0.00031	0.00021	0.00036	0.00039	0.00029
310	15604	19.87	0.00054	0.00037	0.00022	0.00038	0.00046	0.00030
320	15604	20.51	0.00067	0.00046	0.00024	0.00040	0.00057	0.00032
330	15604	21.15	0.00081	0.00056	0.00025	0.00042	0.00069	0.00034
340	15604	21.79	0.00096	0.00066	0.00027	0.00044	0.00081	0.00036
350	15604	22.43	0.00120	0.00080	0.00028	0.00045	0.00100	0.00037
360	15604	23.07	0.00147	0.00096	0.00030	0.00046	0.00122	0.00038
370	15604	23.71	0.00188	0.00122	0.00031	0.00048	0.00155	0.00040
380	15604	24.35	0.00218	0.00138	0.00032	0.00049	0.00178	0.00041

Load (kN)	Area	Stress N/mm^2	Strain				Average strain	
			2				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
390	15604	24.99	0.00287	0.00182	0.00034	0.00050	0.00235	0.00042
400	15604	25.63	0.00470	0.00259	0.00034	0.00054	0.00365	0.00044
390	15604	24.99	0.00589	0.00253	0.00034	0.00059	0.00421	0.00047
380	15604	24.35	0.00560	0.00231	0.00033	0.00058	0.00396	0.00046
370	15604	23.71	0.00449	0.00192	0.00032	0.00053	0.00321	0.00043
380	15604	24.35	0.00452	0.00194	0.00033	0.00053	0.00323	0.00043
390	15604	24.99	0.00471	0.00203	0.00034	0.00055	0.00337	0.00045
400	15604	25.63	0.00525	0.00220	0.00035	0.00056	0.00373	0.00046
410	15604	26.28	0.01021	0.00635	0.00038	0.00051	0.00828	0.00045
420	15604	26.92	0.00688	0.00731	0.00043	0.00059	0.00710	0.00051
410	15604	26.28	0.00790	0.00684	0.00043	0.00061	0.00737	0.00052
400	15604	25.63	0.04503	0.00601	0.00042	0.00062	0.02552	0.00052
410	15604	26.28	0.04414	0.00606	0.00043	0.00063	0.02510	0.00053
420	15604	26.92	0.04611	0.00617	0.00043	0.00064	0.02614	0.00054
400	15604	25.63	-	0.00562	0.00045	0.00072	-	0.00059
410	15604	26.28	-	0.00559	0.00045	0.00072	-	0.00059
420	15604	26.92	-	0.00564	0.00045	0.00073	-	0.00059
430	15604	27.56	-	0.00580	0.00046	0.00074	-	0.00060
440	15604	28.20	-	0.00645	0.00046	0.00080	-	0.00063
440	15604	28.20	-	0.00682	0.00040	0.00012	-	0.00026

Load (kN)	Area	Stress N/mm²	Strain 3 Mid 1	Mid 2	Corner 1	Corner 2	Average strain Mid	Corner
0	15604	0.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	15604	0.64	0.00000	0.00001	0.00002	0.00000	0.00001	0.00001
20	15604	1.28	0.00001	0.00002	0.00003	0.00001	0.00002	0.00002
30	15604	1.92	0.00002	0.00003	0.00004	0.00002	0.00003	0.00003
40	15604	2.56	0.00002	0.00004	0.00005	0.00002	0.00003	0.00004
50	15604	3.20	0.00002	0.00004	0.00005	0.00002	0.00003	0.00004
60	15604	3.85	0.00002	0.00005	0.00006	0.00003	0.00004	0.00005
70	15604	4.49	0.00002	0.00006	0.00007	0.00003	0.00004	0.00005
80	15604	5.13	0.00003	0.00007	0.00008	0.00004	0.00005	0.00006
90	15604	5.77	0.00003	0.00008	0.00009	0.00005	0.00006	0.00007
100	15604	6.41	0.00003	0.00009	0.00009	0.00006	0.00006	0.00008
110	15604	7.05	0.00004	0.00010	0.00010	0.00007	0.00007	0.00009
120	15604	7.69	0.00004	0.00011	0.00011	0.00007	0.00008	0.00009
130	15604	8.33	0.00004	0.00012	0.00011	0.00008	0.00008	0.00010
140	15604	8.97	0.00005	0.00013	0.00012	0.00009	0.00009	0.00011
150	15604	9.61	0.00005	0.00014	0.00013	0.00010	0.00010	0.00012
160	15604	10.25	0.00006	0.00015	0.00014	0.00011	0.00011	0.00013
170	15604	10.89	0.00006	0.00016	0.00015	0.00012	0.00011	0.00014
180	15604	11.54	0.00007	0.00017	0.00015	0.00013	0.00012	0.00014
190	15604	12.18	0.00007	0.00017	0.00017	0.00014	0.00012	0.00016
200	15604	12.82	0.00008	0.00018	0.00018	0.00016	0.00013	0.00017
210	15604	13.46	0.00008	0.00020	0.00018	0.00017	0.00014	0.00018
220	15604	14.10	0.00009	0.00020	0.00019	0.00018	0.00015	0.00019
230	15604	14.74	0.00009	0.00021	0.00020	0.00019	0.00015	0.00020
240	15604	15.38	0.00010	0.00022	0.00021	0.00021	0.00016	0.00021
250	15604	16.02	0.00010	0.00023	0.00022	0.00022	0.00017	0.00022
260	15604	16.66	0.00011	0.00024	0.00023	0.00024	0.00018	0.00024
270	15604	17.30	0.00012	0.00026	0.00024	0.00026	0.00019	0.00025
280	15604	17.94	0.00013	0.00029	0.00025	0.00031	0.00021	0.00028
290	15604	18.58	0.00013	0.00029	0.00025	0.00031	0.00021	0.00028
300	15604	19.23	0.00014	0.00031	0.00026	0.00033	0.00023	0.00030
310	15604	19.87	0.00015	0.00033	0.00027	0.00035	0.00024	0.00031
320	15604	20.51	0.00015	0.00035	0.00027	0.00037	0.00025	0.00032
330	15604	21.15	0.00017	0.00038	0.00028	0.00040	0.00028	0.00034
340	15604	21.79	0.00019	0.00042	0.00029	0.00043	0.00031	0.00036
350	15604	22.43	0.00021	0.00051	0.00030	0.00050	0.00036	0.00040
360	15604	23.07	0.00023	0.00056	0.00031	0.00054	0.00040	0.00043
370	15604	23.71	0.00026	0.00063	0.00032	0.00058	0.00045	0.00045

Load (kN)	Area	Stress N/mm²	Strain 3				Average strain	
			Mid 1	Mid 2	Corner 1	Corner 2	Mid	Corner
380	15604	24.35	0.00030	0.00071	0.00033	0.00063	0.00051	0.00048
390	15604	24.99	0.00034	0.00081	0.00034	0.00070	0.00058	0.00052
400	15604	25.63	0.00044	0.00105	0.00035	0.00082	0.00075	0.00059
410	15604	26.28	0.00050	0.00122	0.00036	0.00090	0.00086	0.00063
420	15604	26.92	0.00064	0.00162	0.00038	0.00102	0.00113	0.00070
430	15604	27.56	0.00085	0.00217	0.00040	0.00116	0.00151	0.00078
420	15604	26.92	0.00086	0.00220	0.00039	0.00117	0.00153	0.00078
410	15604	26.28	0.00086	0.00221	0.00040	0.00117	0.00154	0.00079
420	15604	26.92	0.00090	0.00232	0.00041	0.00122	0.00161	0.00082
430	15604	27.56	0.00107	0.00257	0.00045	0.00132	0.00182	0.00089
440	15604	28.20	0.00143	0.00351	0.00052	0.00166	0.00247	0.00109
430	15604	27.56	0.00148	0.00366	0.00052	0.00169	0.00257	0.00111
420	15604	26.92	0.00134	0.00374	0.00052	0.00170	0.00254	0.00111
430	15604	27.56	0.00142	0.00400	0.00053	0.00177	0.00271	0.00115

Table A.12: Lateral strain of specimen S2R0

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			1				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
0	15604	0.00	-0.00002	0.00000	0.00000	-0.00013	-0.00001	-0.00007
10	15604	0.64	-0.00003	0.00000	0.00000	-0.00037	-0.00002	-0.00019
20	15604	1.28	-0.00004	-0.00001	0.00001	-0.00042	-0.00003	-0.00021
30	15604	1.92	-0.00003	0.00000	0.00001	-0.00051	-0.00002	-0.00025
40	15604	2.56	-0.00001	0.00000	0.00001	-0.00059	-0.00001	-0.00029
50	15604	3.20	0.00000	0.00000	0.00001	-0.00061	0.00000	-0.00030
60	15604	3.85	-0.00002	-0.00001	0.00000	-0.00085	-0.00002	-0.00043
70	15604	4.49	-0.00003	-0.00001	0.00001	-0.00088	-0.00002	-0.00044
80	15604	5.13	-0.00004	-0.00001	0.00002	-0.00085	-0.00003	-0.00042
90	15604	5.77	-0.00004	-0.00001	0.00002	-0.00081	-0.00003	-0.00040
100	15604	6.41	-0.00003	-0.00001	0.00001	-0.00074	-0.00002	-0.00037
110	15604	7.05	-0.00006	-0.00001	0.00002	-0.00061	-0.00004	-0.00030
120	15604	7.69	-0.00004	-0.00001	0.00002	-0.00058	-0.00003	-0.00028
130	15604	8.33	-0.00004	-0.00001	0.00003	-0.00026	-0.00003	-0.00012
140	15604	8.97	-0.00010	-0.00001	0.00003	-0.00005	-0.00006	-0.00001
150	15604	9.61	-0.00010	-0.00001	0.00003	0.00012	-0.00006	0.00008
160	15604	10.25	-0.00006	-0.00001	0.00003	0.00039	-0.00004	0.00021
170	15604	10.89	-0.00003	-0.00001	0.00002	0.00056	-0.00002	0.00029
180	15604	11.54	-0.00010	-0.00001	0.00004	0.00080	-0.00006	0.00042
190	15604	12.18	-0.00004	-0.00001	0.00004	0.00136	-0.00003	0.00070
200	15604	12.82	-0.00004	-0.00001	0.00004	0.00194	-0.00003	0.00099
210	15604	13.46	-0.00005	-0.00001	0.00004	0.00237	-0.00003	0.00121
220	15604	14.10	-0.00003	-0.00001	0.00004	0.00296	-0.00002	0.00150
230	15604	14.74	-0.00002	-0.00001	0.00004	0.00370	-0.00002	0.00187
240	15604	15.38	-0.00003	-0.00002	0.00005	0.00470	-0.00003	0.00238
250	15604	16.02	-0.00003	-0.00001	0.00006	0.00552	-0.00002	0.00279
260	15604	16.66	-0.00002	-0.00001	0.00006	0.00661	-0.00002	0.00334
270	15604	17.30	-0.00004	-0.00002	0.00005	0.00752	-0.00003	0.00379
280	15604	17.94	-0.00004	-0.00001	0.00007	0.00909	-0.00003	0.00458
290	15604	18.58	-0.00001	-0.00002	0.00006	0.01057	-0.00002	0.00532
300	15604	19.23	-0.00005	-0.00001	0.00008	0.01161	-0.00003	0.00585
310	15604	19.87	-0.00005	-0.00001	0.00008	0.01297	-0.00003	0.00653
320	15604	20.51	-0.00003	-0.00001	0.00009	0.01444	-0.00002	0.00727
330	15604	21.15	-0.00001	-0.00002	0.00009	0.01464	-0.00002	0.00737
340	15604	21.79	-0.00001	-0.00001	0.00009	0.01489	-0.00001	0.00749
350	15604	22.43	-0.00001	-0.00002	0.00010	0.01467	-0.00002	0.00739
360	15604	23.07	-0.00001	-0.00001	0.00011	0.01504	-0.00001	0.00758
370	15604	23.71	-0.00001	-0.00001	0.00011	0.01550	-0.00001	0.00781
380	15604	24.35	0.00000	-0.00001	0.00014	0.01622	-0.00001	0.00818
390	15604	24.99	0.00003	0.00000	0.00014	0.01702	0.00002	0.00858
400	15604	25.63	0.00001	-0.00001	0.00015	0.01757	0.00000	0.00886

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			1				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
410	15604	26.28	0.00003	0.00000	0.00016	0.01709	0.00002	0.00863
420	15604	26.92	0.00006	0.00000	0.00018	0.01566	0.00003	0.00792
430	15604	27.56	0.00007	-0.00001	0.00018	0.01479	0.00003	0.00749
440	15604	28.20	0.00007	0.00000	0.00020	0.01437	0.00004	0.00729
450	15604	28.84	0.00011	0.00000	0.00021	0.01342	0.00006	0.00682
460	15604	29.48	0.00015	0.00001	0.00022	0.01252	0.00008	0.00637
470	15604	30.12	0.00017	0.00001	0.00023	0.01239	0.00009	0.00631
480	15604	30.76	0.00019	0.00001	0.00024	0.01268	0.00010	0.00646
490	15604	31.40	0.00023	0.00001	0.00026	0.01428	0.00012	0.00727
500	15604	32.04	0.00024	0.00001	0.00027	0.01397	0.00013	0.00712
510	15604	32.68	0.00036	0.00002	0.00030	0.01207	0.00019	0.00619
520	15604	33.32	0.00050	0.00003	0.00034	0.01048	0.00027	0.00541
530	15604	33.97	0.00073	0.00005	0.00033	0.01226	0.00039	0.00630
540	15604	34.61	0.00083	0.00005	0.00031	0.02142	0.00044	0.01087
550	15604	35.25	0.00094	0.00006	0.00033	0.02649	0.00050	0.01341
560	15604	35.89	0.00102	0.00007	0.00031	0.03118	0.00055	0.01575
570	15604	36.53	0.00113	0.00009	0.00037	0.03833	0.00061	0.01935
560	15604	35.89	0.00120	0.00011	0.00047	0.05135	0.00066	0.02591
550	15604	35.25	0.00117	0.00009	0.00051	0.05218	0.00063	0.02635
540	15604	34.61	0.00109	0.00009	0.00052	0.05271	0.00059	0.02662
550	15604	35.25	0.00108	0.00008	0.00050	0.05537	0.00058	0.02794
560	15604	35.89	0.00107	0.00008	0.00053	0.05772	0.00058	0.02913
570	15604	36.53	0.00111	0.00009	0.00055	0.05723	0.00060	0.02889
580	15604	37.17	0.00112	0.00010	0.00062	0.05707	0.00061	0.02885
570	15604	36.53	0.00117	0.00012	0.00073	0.05544	0.00065	0.02809
560	15604	35.89	0.00119	0.00012	0.00075	0.05416	0.00066	0.02746
550	15604	35.25	0.00115	0.00011	0.00072	0.05304	0.00063	0.02688
560	15604	35.89	0.00113	0.00010	0.00070	0.05218	0.00062	0.02644
570	15604	36.53	0.00108	0.00010	0.00071	0.05170	0.00059	0.02621
580	15604	37.17	0.00117	0.00011	0.00076	0.05145	0.00064	0.02611
590	15604	37.81	0.00119	0.00013	0.00091	0.05085	0.00066	0.02588
580	15604	37.17	0.00128	0.00016	0.00122	0.04921	0.00072	0.02522
570	15604	36.53	0.00125	0.00016	0.00116	0.04865	0.00071	0.02491
560	15604	35.89	0.00124	0.00014	0.00110	0.04852	0.00069	0.02481
550	15604	35.25	0.00119	0.00013	0.00096	0.04812	0.00066	0.02454
560	15604	35.89	0.00115	0.00013	0.00088	0.04803	0.00064	0.02446
570	15604	36.53	0.00115	0.00013	0.00087	0.04802	0.00064	0.02445
580	15604	37.17	0.00119	0.00014	0.00090	0.04801	0.00067	0.02446
590	15604	37.81	0.00121	0.00015	0.00095	0.04811	0.00068	0.02453
580	15604	37.17	0.00125	0.00016	0.00102	0.04854	0.00071	0.02478
570	15604	36.53	0.00126	0.00018	0.00099	0.05342	0.00072	0.02721

Load (kN)	Area	Stress N/mm^2	Strain				Average strain	
			1				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
560	15604	35.89	0.00122	0.00018	0.00067	0.05216	0.00070	0.02642
550	15604	35.25	0.00119	0.00017	0.00059	0.05128	0.00068	0.02594
560	15604	35.89	0.00114	0.00015	0.00046	0.05217	0.00065	0.02632
570	15604	36.53	0.00112	0.00016	0.00047	0.05296	0.00064	0.02672
580	15604	37.17	0.00116	0.00017	0.00049	0.05476	0.00067	0.02763
590	15604	37.81	0.00120	0.00019	0.00054	0.05855	0.00070	0.02955

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			2				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
0	15604	0.00	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
10	15604	0.64	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
20	15604	1.28	0.00000	-0.00001	0.00000	-0.00001	-0.00001	-0.00001
30	15604	1.92	0.00000	-0.00001	0.00000	-0.00001	-0.00001	-0.00001
40	15604	2.56	0.00000	-0.00001	0.00001	-0.00001	-0.00001	0.00000
50	15604	3.20	-0.00001	-0.00001	0.00001	-0.00001	-0.00001	0.00000
60	15604	3.85	-0.00004	-0.00005	-0.00002	0.00001	-0.00005	-0.00001
70	15604	4.49	-0.00004	-0.00006	-0.00002	0.00001	-0.00005	-0.00001
80	15604	5.13	-0.00004	-0.00006	-0.00001	0.00002	-0.00005	0.00001
90	15604	5.77	-0.00004	-0.00006	0.00000	0.00002	-0.00005	0.00001
100	15604	6.41	-0.00003	-0.00005	0.00000	0.00002	-0.00004	0.00001
110	15604	7.05	-0.00003	-0.00006	0.00001	0.00002	-0.00005	0.00002
120	15604	7.69	-0.00003	-0.00005	0.00002	0.00003	-0.00004	0.00003
130	15604	8.33	-0.00003	-0.00005	0.00002	0.00003	-0.00004	0.00003
140	15604	8.97	-0.00003	-0.00005	-0.00002	0.00003	-0.00004	0.00001
150	15604	9.61	-0.00002	-0.00005	-0.00008	0.00004	-0.00004	-0.00002
160	15604	10.25	-0.00002	-0.00004	-0.00011	0.00004	-0.00003	-0.00004
170	15604	10.89	-0.00002	-0.00004	-0.00012	0.00004	-0.00003	-0.00004
180	15604	11.54	-0.00002	-0.00003	-0.00013	0.00005	-0.00003	-0.00004
190	15604	12.18	-0.00001	-0.00003	-0.00013	0.00005	-0.00002	-0.00004
200	15604	12.82	-0.00001	-0.00002	-0.00013	0.00006	-0.00002	-0.00004
210	15604	13.46	-0.00001	-0.00001	-0.00012	0.00006	-0.00001	-0.00003
220	15604	14.10	-0.00001	0.00000	-0.00011	0.00007	-0.00001	-0.00002
230	15604	14.74	-0.00001	0.00000	-0.00009	0.00007	-0.00001	-0.00001
240	15604	15.38	0.00000	0.00001	-0.00007	0.00007	0.00001	0.00000
250	15604	16.02	0.00000	0.00002	-0.00006	0.00008	0.00001	0.00001
260	15604	16.66	0.00000	0.00003	-0.00002	0.00009	0.00002	0.00004
270	15604	17.30	0.00000	0.00003	0.00002	0.00009	0.00002	0.00006
280	15604	17.94	0.00001	0.00005	0.00009	0.00010	0.00003	0.00010
290	15604	18.58	0.00001	0.00005	0.00014	0.00010	0.00003	0.00012
300	15604	19.23	0.00001	0.00007	0.00022	0.00011	0.00004	0.00017
310	15604	19.87	0.00002	0.00008	0.00028	0.00012	0.00005	0.00020
320	15604	20.51	0.00002	0.00010	0.00032	0.00012	0.00006	0.00022
330	15604	21.15	0.00003	0.00011	0.00041	0.00012	0.00007	0.00027
340	15604	21.79	0.00003	0.00013	0.00048	0.00013	0.00008	0.00031
350	15604	22.43	0.00004	0.00014	0.00054	0.00013	0.00009	0.00034
360	15604	23.07	0.00004	0.00016	0.00063	0.00014	0.00010	0.00039
370	15604	23.71	0.00005	0.00018	0.00063	0.00014	0.00012	0.00039
380	15604	24.35	0.00006	0.00022	0.00062	0.00015	0.00014	0.00039
390	15604	24.99	0.00006	0.00025	0.00062	0.00016	0.00016	0.00039
400	15604	25.63	0.00007	0.00029	0.00066	0.00017	0.00018	0.00042

Load (kN)	Area	Stress N/mm²	Strain 2				Average strain	
			Mid 1	Mid 2	Corner 1	Corner 2	Mid	Corner
410	15604	26.28	0.00007	0.00033	0.00075	0.00019	0.00020	0.00047
420	15604	26.92	0.00008	0.00037	-0.00196	0.00021	0.00023	-0.00088
430	15604	27.56	0.00009	0.00047	-0.00855	0.00024	0.00028	-0.00416
440	15604	28.20	0.00009	0.00052	-0.00985	0.00026	0.00031	-0.00480
450	15604	28.84	0.00009	0.00061	-0.01065	0.00030	0.00035	-0.00518
460	15604	29.48	0.00010	0.00068	-0.01103	0.00033	0.00039	-0.00535
470	15604	30.12	0.00010	0.00081	-0.01194	0.00039	0.00046	-0.00578
480	15604	30.76	0.00011	0.00109	-0.01382	0.00051	0.00060	-0.00666
490	15604	31.40	0.00011	0.00125	-0.01425	0.00059	0.00068	-0.00683
500	15604	32.04	0.00011	0.00138	-0.01463	0.00066	0.00075	-0.00699
510	15604	32.68	0.00011	0.00153	-0.01473	0.00072	0.00082	-0.00701
520	15604	33.32	0.00012	0.00179	-0.01544	0.00084	0.00096	-0.00730
530	15604	33.97	0.00013	0.00202	-0.01808	0.00096	0.00108	-0.00856
540	15604	34.61	0.00016	0.00226	-0.02335	0.00111	0.00121	-0.01112
550	15604	35.25	0.00021	0.00260	-0.02601	0.00136	0.00141	-0.01233
540	15604	34.61	0.00021	0.00263	-0.02600	0.00132	0.00142	-0.01234
530	15604	33.97	0.00020	0.00261	-0.02588	0.00129	0.00141	-0.01230
520	15604	33.32	0.00020	0.00259	-0.02593	0.00125	0.00140	-0.01234
530	15604	33.97	0.00020	0.00265	-0.02586	0.00128	0.00143	-0.01229
540	15604	34.61	0.00021	0.00274	-0.02568	0.00135	0.00148	-0.01217
550	15604	35.25	0.00022	0.00279	-0.02533	0.00140	0.00151	-0.01197
560	15604	35.89	0.00023	0.00288	-0.02487	0.00148	0.00156	-0.01170
550	15604	35.25	0.00025	0.00309	-0.02539	0.00170	0.00167	-0.01185
540	15604	34.61	0.00025	0.00311	-0.02462	0.00173	0.00168	-0.01145
530	15604	33.97	0.00025	0.00310	-0.02291	0.00172	0.00168	-0.01060
540	15604	34.61	0.00024	0.00309	-0.01827	0.00169	0.00167	-0.00829
550	15604	35.25	0.00025	0.00314	-0.01851	0.00174	0.00170	-0.00839
560	15604	35.89	0.00025	0.00315	-0.01850	0.00176	0.00170	-0.00837
550	15604	35.25	0.00025	0.00321	-0.01864	0.00182	0.00173	-0.00841
540	15604	34.61	0.00026	0.00327	-0.01892	0.00188	0.00177	-0.00852
550	15604	35.25	0.00029	0.00339	-0.01784	0.00211	0.00184	-0.00787
560	15604	35.89	0.00027	0.00335	-0.02024	0.00207	0.00181	-0.00909
570	15604	36.53	0.00028	0.00342	-0.01968	0.00216	0.00185	-0.00876
560	15604	35.89	0.00028	0.00348	-0.01998	0.00225	0.00188	-0.00887
550	15604	35.25	0.00030	0.00358	-0.02118	0.00245	0.00194	-0.00937

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			3				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
0	15604	0.00	0.00001	0.00002	-0.00001	-0.00001	0.00002	-0.00001
10	15604	0.64	-0.00001	0.00000	-0.00002	-0.00001	-0.00001	-0.00002
20	15604	1.28	-0.00001	0.00002	0.00001	0.00000	0.00001	0.00001
30	15604	1.92	0.00003	0.00004	-0.00002	0.00000	0.00004	-0.00001
40	15604	2.56	-0.00001	0.00002	0.00001	0.00001	0.00001	0.00001
50	15604	3.20	0.00002	0.00002	-0.00001	0.00001	0.00002	0.00000
60	15604	3.85	-0.00001	0.00002	-0.00029	-0.00002	0.00001	-0.00016
70	15604	4.49	0.00003	0.00004	-0.00036	-0.00002	0.00004	-0.00019
80	15604	5.13	-0.00001	0.00003	-0.00036	-0.00001	0.00001	-0.00019
90	15604	5.77	-0.00001	0.00007	-0.00038	0.00000	0.00003	-0.00019
100	15604	6.41	0.00000	0.00008	-0.00039	0.00000	0.00004	-0.00020
110	15604	7.05	0.00003	0.00007	-0.00041	0.00001	0.00005	-0.00020
120	15604	7.69	0.00003	0.00009	-0.00037	0.00002	0.00006	-0.00018
130	15604	8.33	0.00004	0.00008	-0.00026	0.00002	0.00006	-0.00012
140	15604	8.97	0.00000	0.00007	-0.00011	-0.00002	0.00004	-0.00007
150	15604	9.61	0.00004	0.00009	0.00007	-0.00008	0.00007	-0.00001
160	15604	10.25	0.00004	0.00012	0.00021	-0.00011	0.00008	0.00005
170	15604	10.89	0.00001	0.00008	0.00026	-0.00012	0.00005	0.00007
180	15604	11.54	0.00005	0.00009	0.00027	-0.00013	0.00007	0.00007
190	15604	12.18	0.00005	0.00012	0.00033	-0.00013	0.00009	0.00010
200	15604	12.82	0.00003	0.00010	0.00035	-0.00013	0.00007	0.00011
210	15604	13.46	0.00004	0.00010	0.00039	-0.00013	0.00007	0.00013
220	15604	14.10	0.00003	0.00011	0.00043	-0.00037	0.00007	0.00003
230	15604	14.74	0.00008	0.00014	0.00043	-0.00042	0.00011	0.00001
240	15604	15.38	0.00009	0.00013	0.00045	-0.00051	0.00011	-0.00003
250	15604	16.02	0.00005	0.00014	0.00052	-0.00059	0.00010	-0.00004
260	15604	16.66	0.00007	0.00016	0.00057	-0.00061	0.00012	-0.00002
270	15604	17.30	0.00008	0.00018	0.00061	-0.00085	0.00013	-0.00012
280	15604	17.94	0.00011	0.00018	0.00062	-0.00088	0.00015	-0.00013
290	15604	18.58	0.00011	0.00019	0.00066	-0.00085	0.00015	-0.00010
300	15604	19.23	0.00009	0.00020	0.00074	-0.00081	0.00015	-0.00004
310	15604	19.87	0.00012	0.00021	0.00075	-0.00074	0.00017	0.00000
320	15604	20.51	0.00009	0.00021	0.00082	-0.00061	0.00015	0.00011
330	15604	21.15	0.00010	0.00023	0.00058	-0.00058	0.00017	0.00000
340	15604	21.79	0.00010	0.00022	0.00045	-0.00026	0.00016	0.00010
350	15604	22.43	0.00012	0.00023	0.00040	-0.00005	0.00018	0.00018
360	15604	23.07	0.00012	0.00024	0.00056	0.00012	0.00018	0.00034
370	15604	23.71	0.00015	0.00029	0.00098	0.00039	0.00022	0.00069
380	15604	24.35	0.00014	0.00029	0.00110	0.00056	0.00022	0.00083
390	15604	24.99	0.00017	0.00031	0.00114	0.00080	0.00024	0.00097
400	15604	25.63	0.00019	0.00031	0.00116	0.00084	0.00025	0.00100

Load (kN)	Area	Stress N/mm²	Strain				Average strain	
			3				Mid	Corner
			Mid 1	Mid 2	Corner 1	Corner 2		
410	15604	26.28	0.00018	0.00032	0.00126	0.00096	0.00025	0.00111
420	15604	26.92	0.00020	0.00030	0.00128	0.00111	0.00025	0.00120
430	15604	27.56	0.00020	0.00036	0.00113	0.00136	0.00028	0.00125
440	15604	28.20	0.00019	0.00035	0.00090	0.00132	0.00027	0.00111
450	15604	28.84	0.00020	0.00035	0.00063	0.00129	0.00028	0.00096
460	15604	29.48	0.00028	0.00042	0.00059	0.00125	0.00035	0.00092
470	15604	30.12	0.00025	0.00044	0.00065	0.00128	0.00035	0.00097
480	15604	30.76	0.00027	0.00046	0.00077	0.00135	0.00037	0.00106
490	15604	31.40	0.00034	0.00047	0.00108	0.00140	0.00041	0.00124
500	15604	32.04	0.00037	0.00054	0.00190	0.00148	0.00046	0.00169
510	15604	32.68	0.00038	0.00057	0.00202	0.00170	0.00048	0.00186
520	15604	33.32	0.00043	0.00061	0.00173	0.00173	0.00052	0.00173
530	15604	33.97	0.00050	0.00067	0.00186	0.00172	0.00059	0.00179
540	15604	34.61	0.00055	0.00074	0.00233	0.00169	0.00065	0.00201
550	15604	35.25	0.00059	0.00084	0.00177	0.00174	0.00072	0.00176
560	15604	35.89	0.00073	0.00101	0.00193	0.00176	0.00087	0.00185
570	15604	36.53	0.00076	0.00111	0.00299	0.00182	0.00094	0.00241
580	15604	37.17	0.00089	0.00126	0.00225	0.00188	0.00108	0.00207
590	15604	37.81	0.00096	0.00144	-0.00090	0.00211	0.00120	0.00061
580	15604	37.17	0.00108	0.00164	-0.00084	0.00207	0.00136	0.00062
590	15604	37.81	0.00108	0.00168	-0.00050	0.00216	0.00138	0.00083
600	15604	38.45	0.00112	0.00173	0.00019	0.00225	0.00143	0.00122
610	15604	39.09	0.00129	0.00213	0.00032	0.00245	0.00171	0.00139
620	15604	39.73	0.00171	0.00248	-0.00330	0.00260	0.00210	-0.00035
610	15604	39.09	0.00182	0.00202	-0.00413	0.00263	0.00192	-0.00075
600	15604	38.45	0.00180	0.00177	-0.00496	0.00261	0.00179	-0.00118
610	15604	39.09	0.00188	0.00164	-0.00563	0.00259	0.00176	-0.00152
620	15604	39.73	0.00200	0.00164	-0.00683	0.00265	0.00182	-0.00209
630	15604	40.37	0.00219	0.00173	-0.00831	0.00274	0.00196	-0.00279
620	15604	39.73	0.00270	0.00160	-0.01300	0.00279	0.00215	-0.00511
610	15604	39.09	0.00283	0.00145	-0.01471	0.00288	0.00214	-0.00592
600	15604	38.45	0.00283	0.00122	-0.01601	0.00309	0.00203	-0.00646
610	15604	39.09	0.00297	0.00121	-0.01807	0.00311	0.00209	-0.00748
620	15604	39.73	0.00304	0.00122	-0.01952	0.00310	0.00213	-0.00821
630	15604	40.37	0.00320	0.00095	-0.02041	0.00309	0.00208	-0.00866
620	15604	39.73	0.00382	-0.00289	-0.02392	0.00314	0.00047	-0.01039
610	15604	39.09	0.00382	-0.00452	-0.02500	0.00315	-0.00035	-0.01093
620	15604	39.73	0.00393	-0.00644	-0.02549	0.00321	-0.00126	-0.01114
630	15604	40.37	0.00409	-0.00748	-0.02679	0.00327	-0.00170	-0.01176

Table A.13: Lateral strain of specimen S1R1

Load (kN)	Area mm^2	Stress N/mm^2	Strain 1 Mid	Left	Center	Right
0	15432	0.00	0.00000	0.00000	0.00000	0.00000
10	15432	0.65	0.00000	-0.00001	-0.00001	-0.00001
20	15432	1.30	0.00000	-0.00001	-0.00001	-0.00001
30	15432	1.94	-0.00001	-0.00001	-0.00002	-0.00002
40	15432	2.59	-0.00001	-0.00002	0.00000	-0.00002
50	15432	3.24	-0.00001	-0.00001	-0.00001	-0.00002
60	15432	3.89	0.00000	-0.00001	-0.00001	-0.00001
70	15432	4.54	0.00000	-0.00002	0.00000	-0.00001
80	15432	5.18	0.00000	-0.00001	-0.00001	-0.00002
90	15432	5.83	0.00000	0.00000	-0.00002	-0.00003
100	15432	6.48	0.00000	-0.00001	-0.00002	-0.00003
110	15432	7.13	0.00000	-0.00001	-0.00003	-0.00005
120	15432	7.78	0.00000	-0.00001	-0.00004	-0.00005
130	15432	8.42	0.00000	-0.00001	-0.00004	-0.00005
140	15432	9.07	0.00000	0.00000	-0.00004	-0.00005
150	15432	9.72	0.00001	-0.00001	-0.00003	-0.00005
160	15432	10.37	0.00001	0.00001	-0.00003	-0.00005
170	15432	11.02	0.00002	0.00002	-0.00003	-0.00004
180	15432	11.66	0.00002	0.00003	-0.00002	-0.00003
190	15432	12.31	0.00003	0.00003	-0.00002	-0.00003
200	15432	12.96	0.00003	0.00004	-0.00001	-0.00002
210	15432	13.61	0.00004	0.00005	-0.00001	-0.00001
220	15432	14.26	0.00004	0.00006	0.00000	0.00000
230	15432	14.90	0.00005	0.00007	0.00002	0.00002
240	15432	15.55	0.00006	0.00007	0.00003	0.00004
250	15432	16.20	0.00007	0.00010	0.00003	0.00006
260	15432	16.85	0.00008	0.00010	0.00004	0.00007
270	15432	17.50	0.00008	0.00012	0.00005	0.00009
280	15432	18.14	0.00010	0.00014	0.00006	0.00011
290	15432	18.79	0.00011	0.00016	0.00007	0.00013
300	15432	19.44	0.00013	0.00018	0.00008	0.00015
310	15432	20.09	0.00015	0.00021	0.00011	0.00018
320	15432	20.74	0.00019	0.00027	0.00012	0.00023
330	15432	21.38	0.00021	0.00031	0.00013	0.00026
340	15432	22.03	0.00024	0.00035	0.00015	0.00030
350	15432	22.68	0.00028	0.00040	0.00017	0.00035

Load (kN)	Area mm^2	Stress N/mm^2	Strain			
			1			
			Mid	Left	Center	Right
360	15432	23.33	0.00032	0.00047	0.00019	0.00041
370	15432	23.98	0.00038	0.00056	0.00022	0.00049
380	15432	24.62	0.00047	0.00069	0.00026	0.00061
390	15432	25.27	0.00056	0.00083	0.00030	0.00074
400	15432	25.92	0.00069	0.00104	0.00036	0.00095
410	15432	26.57	0.00079	0.00120	0.00041	0.00111
420	15432	27.22	0.00100	0.00138	0.00047	0.00133
430	15432	27.86	0.00125	0.00146	0.00050	0.00152
440	15432	28.51	0.00148	0.00159	0.00055	0.00179
450	15432	29.16	0.00181	0.00185	0.00065	0.00230
460	15432	29.81	0.00175	0.00234	0.00088	0.00309
450	15432	29.16	0.00171	0.00235	0.00088	0.00308
440	15432	28.51	0.00165	0.00234	0.00087	0.00304
430	15432	27.86	0.00159	0.00232	0.00086	0.00300
440	15432	28.51	0.00158	0.00233	0.00087	0.00302
450	15432	29.16	0.00162	0.00237	0.00089	0.00308
460	15432	29.81	0.00169	0.00245	0.00092	0.00319
470	15432	30.46	0.00176	0.00254	0.00095	0.00332
480	15432	31.10	0.00195	0.00286	0.00101	0.00336
470	15432	30.46	0.00192	0.00289	0.00101	0.00333
460	15432	29.81	0.00186	0.00288	0.00098	0.00326
450	15432	29.16	0.00184	0.00287	0.00097	0.00324
460	15432	29.81	0.00186	0.00290	0.00098	0.00327
470	15432	30.46	0.00189	0.00292	0.00099	0.00329
480	15432	31.10	0.00193	0.00295	0.00099	0.00332
490	15432	31.75	0.00198	0.00302	0.00100	0.00335

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
0	15432	0.00	-0.00001	0.00000	-0.00002	0.00000
10	15432	0.65	-0.00002	-0.00001	0.00000	-0.00001
20	15432	1.30	-0.00002	-0.00001	-0.00001	-0.00002
30	15432	1.94	-0.00003	-0.00001	-0.00002	-0.00002
40	15432	2.59	-0.00001	-0.00001	-0.00001	-0.00003
50	15432	3.24	-0.00002	-0.00001	-0.00002	-0.00004
60	15432	3.89	-0.00002	-0.00001	-0.00002	-0.00004
70	15432	4.54	-0.00003	-0.00002	-0.00002	-0.00003
80	15432	5.18	-0.00002	-0.00001	-0.00002	-0.00005
90	15432	5.83	-0.00003	-0.00002	-0.00002	-0.00005
100	15432	6.48	-0.00004	-0.00002	-0.00002	-0.00004
110	15432	7.13	-0.00004	-0.00002	-0.00003	-0.00004
120	15432	7.78	-0.00004	-0.00001	-0.00002	-0.00003
130	15432	8.42	-0.00003	-0.00001	-0.00003	-0.00002
140	15432	9.07	-0.00003	-0.00001	-0.00003	-0.00001
150	15432	9.72	-0.00004	0.00000	-0.00003	0.00000
160	15432	10.37	-0.00004	0.00000	-0.00003	0.00003
170	15432	11.02	-0.00003	0.00001	-0.00003	0.00005
180	15432	11.66	-0.00004	0.00000	-0.00002	0.00007
190	15432	12.31	-0.00003	0.00000	-0.00002	0.00009
200	15432	12.96	-0.00002	0.00001	-0.00002	0.00011
210	15432	13.61	-0.00002	0.00001	-0.00002	0.00012
220	15432	14.26	-0.00004	0.00001	-0.00003	0.00016
230	15432	14.90	-0.00003	0.00002	-0.00003	0.00018
240	15432	15.55	-0.00003	0.00002	-0.00003	0.00020
250	15432	16.20	-0.00004	0.00002	-0.00003	0.00024
260	15432	16.85	-0.00004	0.00002	-0.00002	0.00029
270	15432	17.50	-0.00003	0.00002	-0.00002	0.00031
280	15432	18.14	-0.00004	0.00002	-0.00003	0.00037
290	15432	18.79	-0.00004	0.00002	-0.00003	0.00043
300	15432	19.44	-0.00004	0.00003	-0.00003	0.00048
310	15432	20.09	-0.00004	0.00004	-0.00004	0.00055
320	15432	20.74	-0.00004	0.00004	-0.00002	0.00060
330	15432	21.38	-0.00003	0.00005	-0.00004	0.00067
340	15432	22.03	-0.00004	0.00005	-0.00003	0.00074
350	15432	22.68	-0.00003	0.00006	-0.00002	0.00089
360	15432	23.33	-0.00002	0.00008	-0.00002	0.00096
370	15432	23.98	-0.00003	0.00009	-0.00002	0.00110
380	15432	24.62	-0.00003	0.00012	-0.00002	0.00125
390	15432	25.27	-0.00003	0.00012	-0.00001	0.00137
400	15432	25.92	-0.00002	0.00016	0.00002	0.00167

Load (kN)	Area	Stress N/mm²	Strain 2 Mid	Left	Center	Right
410	15432	26.57	-0.00001	0.00019	0.00003	0.00185
420	15432	27.22	-0.00001	0.00022	0.00005	0.00199
430	15432	27.86	0.00000	0.00025	0.00008	0.00217
440	15432	28.51	0.00000	0.00031	0.00008	0.00212
450	15432	29.16	-0.00001	0.00034	0.00008	0.00216
440	15432	28.51	-0.00001	0.00033	0.00008	0.00198
430	15432	27.86	-0.00003	0.00032	0.00008	0.00183
440	15432	28.51	-0.00002	0.00033	0.00008	0.00177
450	15432	29.16	-0.00003	0.00035	0.00008	0.00181
460	15432	29.81	-0.00004	0.00037	0.00009	0.00194
450	15432	29.16	-0.00012	0.00038	0.00011	0.00159

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	15432	0.00	-0.00003	0.00000	0.00000	0.00000
10	15432	0.65	-0.00004	0.00002	-0.00001	-0.00001
20	15432	1.30	-0.00005	0.00003	-0.00001	-0.00001
30	15432	1.94	-0.00005	0.00003	-0.00001	-0.00001
40	15432	2.59	-0.00005	0.00003	-0.00001	-0.00001
50	15432	3.24	-0.00005	0.00004	-0.00001	-0.00001
60	15432	3.89	-0.00006	0.00004	-0.00002	-0.00001
70	15432	4.54	-0.00006	0.00005	-0.00003	-0.00001
80	15432	5.18	-0.00006	0.00005	-0.00004	-0.00001
90	15432	5.83	-0.00006	0.00006	-0.00004	-0.00001
100	15432	6.48	-0.00006	0.00006	-0.00006	-0.00001
110	15432	7.13	-0.00006	0.00007	-0.00006	-0.00001
120	15432	7.78	-0.00005	0.00007	-0.00007	-0.00001
130	15432	8.42	-0.00005	0.00007	-0.00007	-0.00001
140	15432	9.07	-0.00005	0.00008	-0.00008	-0.00001
150	15432	9.72	-0.00005	0.00008	-0.00008	-0.00001
160	15432	10.37	-0.00005	0.00009	-0.00008	-0.00001
170	15432	11.02	-0.00005	0.00010	-0.00008	0.00000
180	15432	11.66	-0.00004	0.00010	-0.00009	0.00000
190	15432	12.31	-0.00004	0.00011	-0.00010	0.00001
200	15432	12.96	-0.00004	0.00012	-0.00010	0.00001
210	15432	13.61	-0.00004	0.00013	-0.00011	0.00001
220	15432	14.26	-0.00003	0.00014	-0.00011	0.00002
230	15432	14.90	-0.00002	0.00015	-0.00012	0.00002
240	15432	15.55	-0.00002	0.00016	-0.00013	0.00002
250	15432	16.20	-0.00001	0.00018	-0.00013	0.00003
260	15432	16.85	-0.00001	0.00019	-0.00014	0.00003
270	15432	17.50	0.00000	0.00022	-0.00015	0.00004
280	15432	18.14	0.00001	0.00023	-0.00016	0.00005
290	15432	18.79	0.00002	0.00025	-0.00016	0.00005
300	15432	19.44	0.00003	0.00028	-0.00017	0.00006
310	15432	20.09	0.00004	0.00030	-0.00018	0.00006
320	15432	20.74	0.00005	0.00033	-0.00019	0.00007
330	15432	21.38	0.00007	0.00037	-0.00020	0.00008
340	15432	22.03	0.00008	0.00041	-0.00021	0.00008
350	15432	22.68	0.00010	0.00046	-0.00022	0.00009
360	15432	23.33	0.00011	0.00050	-0.00022	0.00011
370	15432	23.98	0.00013	0.00058	-0.00022	0.00012
380	15432	24.62	0.00015	0.00065	-0.00022	0.00014
390	15432	25.27	0.00016	0.00074	-0.00020	0.00016
400	15432	25.92	0.00017	0.00085	-0.00017	0.00019

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
410	15432	26.57	0.00019	0.00094	-0.00015	0.00021
420	15432	27.22	0.00023	0.00106	-0.00011	0.00025
430	15432	27.86	0.00028	0.00120	-0.00007	0.00029
440	15432	28.51	0.00032	0.00133	-0.00003	0.00033
450	15432	29.16	0.00041	0.00166	0.00008	0.00046
460	15432	29.81	0.00046	0.00197	0.00019	0.00055
470	15432	30.46	0.00052	0.00225	0.00031	0.00062
480	15432	31.10	0.00061	0.00276	0.00060	0.00076
490	15432	31.75	0.00069	0.00310	0.00091	0.00096
500	15432	32.40	0.00090	0.00460	0.00154	0.00175
490	15432	31.75	0.00088	0.00492	0.00160	0.00181
480	15432	31.10	0.00084	0.00516	0.00158	0.00179
470	15432	30.46	0.00082	0.00531	0.00156	0.00175
480	15432	31.10	0.00085	0.00520	0.00158	0.00182
490	15432	31.75	0.00087	0.00499	0.00161	0.00187
500	15432	32.40	0.00094	0.00502	0.00170	0.00200
510	15432	33.05	0.00104	0.00520	0.00184	0.00220

Table A.14: Lateral strain of specimen S2R1

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
0	15432	0.00	0.00000	0.00000	-0.00001	-0.00001
10	15432	0.65	-0.00002	0.00000	-0.00001	-0.00001
20	15432	1.30	0.00001	0.00001	-0.00002	-0.00001
30	15432	1.94	0.00000	0.00001	0.00000	0.00001
40	15432	2.59	0.00000	0.00004	0.00000	0.00003
50	15432	3.24	-0.00002	0.00003	-0.00001	-0.00001
60	15432	3.89	-0.00007	0.00002	-0.00003	-0.00001
70	15432	4.54	-0.00011	0.00002	-0.00004	-0.00001
80	15432	5.18	-0.00012	0.00002	-0.00004	-0.00001
90	15432	5.83	-0.00015	0.00006	-0.00003	0.00000
100	15432	6.48	-0.00038	0.00008	-0.00004	-0.00002
110	15432	7.13	-0.00049	0.00010	-0.00002	0.00001
120	15432	7.78	-0.00072	0.00011	0.00000	0.00003
130	15432	8.42	-0.00093	0.00014	0.00000	0.00003
140	15432	9.07	-0.00102	0.00017	0.00001	0.00007
150	15432	9.72	-0.00112	0.00021	0.00002	0.00009
160	15432	10.37	-0.00107	0.00025	0.00005	0.00012
170	15432	11.02	-0.00096	0.00029	0.00005	0.00014
180	15432	11.66	-0.00089	0.00034	0.00006	0.00018
190	15432	12.31	-0.00088	0.00038	0.00007	0.00020
200	15432	12.96	-0.00077	0.00042	0.00008	0.00023
210	15432	13.61	-0.00067	0.00045	0.00009	0.00027
220	15432	14.26	-0.00031	0.00016	0.00011	0.00030
230	15432	14.90	-0.00012	-0.00247	0.00013	0.00032
240	15432	15.55	-0.00007	-0.01031	0.00016	0.00036
250	15432	16.20	0.00020	-0.01569	0.00016	0.00040
260	15432	16.85	0.00064	-0.02192	0.00019	0.00047
270	15432	17.50	0.00100	-0.02372	0.00021	0.00050
280	15432	18.14	0.00152	-0.01389	0.00024	0.00057
290	15432	18.79	0.00211	-0.00101	0.00027	0.00065
300	15432	19.44	0.00290	-0.01292	0.00033	0.00074
310	15432	20.09	0.00385	-0.02611	0.00040	0.00094
320	15432	20.74	0.00378	-0.03513	0.00044	0.00109
330	15432	21.38	0.00936	-0.04357	0.00054	0.00133
340	15432	22.03	0.01332	-0.07322	0.00062	0.00158
350	15432	22.68	0.01646	-0.08543	0.00070	0.00071
360	15432	23.33	0.02098	-0.09228	0.00086	0.00089
370	15432	23.98	0.02368	-0.09894	0.00101	0.00097
380	15432	24.62	0.02449	-0.10058	0.00107	0.00102
390	15432	25.27	0.02887	-0.10092	0.00124	0.00114

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
400	15432	25.92	0.04014	-0.09311	0.00135	0.00124
410	15432	26.57	0.04657	-0.09841	0.00160	0.00142
420	15432	27.22	0.04670	-0.10466	0.00193	0.00159
430	15432	27.86	0.04691	-0.10603	0.00224	0.00180
440	15432	28.51	0.04703	-0.10646	0.00240	0.00191
450	15432	29.16	0.03296	-0.10791	0.00272	0.00212
440	15432	28.51	0.03141	-0.10654	0.00267	0.00209
430	15432	27.86	0.03062	-0.10871	0.00265	0.00208
440	15432	28.51	0.02974	-0.11536	0.00269	0.00213
450	15432	29.16	0.02981	-0.11691	0.00282	0.00221
460	15432	29.81	0.02904	-0.11598	-0.00070	0.00446
470	15432	30.46	0.02405	-0.09670	-0.00137	0.00538
450	15432	29.16	0.02143	-0.02488	-0.00281	0.00521
440	15432	28.51	0.02131	-0.02234	-0.00284	0.00519

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
0	15432	0.00	0.00000	0.00000	0.00001	0.00000
10	15432	0.65	0.00002	0.00002	0.00002	0.00001
20	15432	1.30	0.00003	0.00003	0.00003	0.00002
30	15432	1.94	0.00005	0.00004	0.00004	0.00003
40	15432	2.59	0.00006	0.00005	0.00005	0.00003
50	15432	3.24	0.00008	0.00007	0.00006	0.00004
60	15432	3.89	0.00010	0.00008	0.00007	0.00006
70	15432	4.54	0.00011	0.00010	0.00009	0.00006
80	15432	5.18	0.00013	0.00011	0.00009	0.00007
90	15432	5.83	0.00014	0.00012	0.00010	0.00008
100	15432	6.48	0.00017	0.00014	0.00011	0.00010
110	15432	7.13	0.00019	0.00016	0.00012	0.00011
120	15432	7.78	0.00020	0.00017	0.00013	0.00011
130	15432	8.42	0.00022	0.00018	0.00014	0.00013
140	15432	9.07	0.00024	0.00020	0.00015	0.00013
150	15432	9.72	0.00025	0.00021	0.00016	0.00014
160	15432	10.37	0.00027	0.00023	0.00017	0.00015
170	15432	11.02	0.00029	0.00024	0.00018	0.00016
180	15432	11.66	0.00030	0.00026	0.00019	0.00017
190	15432	12.31	0.00032	0.00026	0.00019	0.00017
200	15432	12.96	0.00034	0.00028	0.00020	0.00019
210	15432	13.61	0.00035	0.00029	0.00021	0.00019
220	15432	14.26	0.00037	0.00031	0.00023	0.00020
230	15432	14.90	0.00038	0.00032	0.00023	0.00021
240	15432	15.55	0.00040	0.00033	0.00024	0.00022
250	15432	16.20	0.00042	0.00035	0.00025	0.00023
260	15432	16.85	0.00044	0.00036	0.00026	0.00024
270	15432	17.50	0.00046	0.00037	0.00027	0.00024
280	15432	18.14	0.00049	0.00039	0.00028	0.00025
290	15432	18.79	0.00051	0.00041	0.00029	0.00027
300	15432	19.44	0.00053	0.00042	0.00030	0.00028
310	15432	20.09	0.00055	0.00044	0.00031	0.00029
320	15432	20.74	0.00057	0.00046	0.00032	0.00030
330	15432	21.38	0.00060	0.00049	0.00033	0.00031
340	15432	22.03	0.00063	0.00049	0.00034	0.00032
350	15432	22.68	0.00066	0.00052	0.00035	0.00034
360	15432	23.33	0.00070	0.00055	0.00037	0.00036
370	15432	23.98	0.00073	0.00058	0.00038	0.00038
380	15432	24.62	0.00076	0.00061	0.00039	0.00039
390	15432	25.27	0.00079	0.00062	0.00041	0.00041
400	15432	25.92	0.00084	0.00066	0.00043	0.00043

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
410	15432	26.57	0.00087	0.00069	0.00045	0.00045
420	15432	27.22	0.00093	0.00073	0.00047	0.00047
430	15432	27.86	0.00097	0.00077	0.00049	0.00050
440	15432	28.51	0.00102	0.00081	0.00051	0.00053
450	15432	29.16	0.00107	0.00085	0.00053	0.00056
460	15432	29.81	0.00117	0.00092	0.00057	0.00061
470	15432	30.46	0.00122	0.00096	0.00060	0.00065
480	15432	31.10	0.00129	0.00102	0.00063	0.00069
490	15432	31.75	0.00138	0.00109	0.00067	0.00073
500	15432	32.40	0.00149	0.00118	0.00073	0.00080
510	15432	33.05	0.00160	0.00128	0.00079	0.00087
520	15432	33.70	0.00166	0.00132	0.00083	0.00092
530	15432	34.34	0.00173	0.00138	0.00086	0.00096
540	15432	34.99	0.00180	0.00145	0.00091	0.00102
550	15432	35.64	0.00188	0.00153	0.00096	0.00109
560	15432	36.29	0.00201	0.00168	0.00106	0.00121
570	15432	36.94	0.00210	0.00187	0.00119	0.00134
580	15432	37.58	0.00205	0.00203	0.00130	0.00146
590	15432	38.23	0.00206	0.00215	0.00137	0.00155
600	15432	38.88	0.00216	0.00244	0.00154	0.00175
610	15432	39.53	0.00233	0.00278	0.00176	0.00202
620	15432	40.18	0.00260	0.00329	0.00212	0.00244
610	15432	39.53	0.00265	0.00334	0.00218	0.00250
600	15432	38.88	0.00266	0.00336	0.00220	0.00253
610	15432	39.53	0.00271	0.00343	0.00226	0.00260
620	15432	40.18	0.00276	0.00352	0.00232	0.00266
630	15432	40.82	0.00280	0.00359	0.00236	0.00272
640	15432	41.47	0.00284	0.00365	0.00240	0.00277
650	15432	42.12	0.00304	0.00393	0.00260	0.00303
660	15432	42.77	0.00348	0.00457	0.00308	0.00363
670	15432	43.42	0.00365	0.00476	0.00325	0.00385
680	15432	44.06	0.00382	0.00485	0.00343	0.00408
690	15432	44.71	0.00391	0.00491	0.00351	0.00418
680	15432	44.06	0.00404	0.00492	0.00365	0.00436
670	15432	43.42	0.00405	0.00487	0.00367	0.00439
680	15432	44.06	0.00408	0.00491	0.00370	0.00443
690	15432	44.71	0.00412	0.00493	0.00374	0.00448
700	15432	45.36	0.00427	0.00492	0.00389	0.00465
710	15432	46.01	0.00442	0.00487	0.00409	0.00490
720	15432	46.66	0.00450	0.00488	0.00418	0.00500
730	15432	47.30	0.00467	0.00482	0.00435	0.00521

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
720	15432	46.66	0.00470	0.00476	0.00439	0.00525
710	15432	46.01	0.00470	0.00472	0.00441	0.00527
700	15432	45.36	0.00469	0.00466	0.00443	0.00529
690	15432	44.71	0.00467	0.00460	0.00444	0.00530
700	15432	45.36	0.00470	0.00461	0.00447	0.00533
710	15432	46.01	0.00473	0.00462	0.00451	0.00537
720	15432	46.66	0.00480	0.00463	0.00457	0.00545
730	15432	47.30	0.00487	0.00463	0.00463	0.00551

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	15432	0.00	-0.00002	0.00000	0.00000	-0.00001
10	15432	0.65	-0.00002	0.00002	0.00001	-0.00001
20	15432	1.30	-0.00001	0.00003	0.00002	0.00000
30	15432	1.94	-0.00001	0.00005	0.00004	0.00003
40	15432	2.59	-0.00001	0.00005	0.00004	0.00004
50	15432	3.24	-0.00001	0.00006	0.00004	0.00005
60	15432	3.89	-0.00001	0.00007	0.00005	0.00009
70	15432	4.54	-0.00001	0.00007	0.00005	0.00017
80	15432	5.18	-0.00001	0.00009	0.00006	0.00021
90	15432	5.83	-0.00001	0.00010	0.00007	0.00028
100	15432	6.48	-0.00001	0.00011	0.00007	0.00041
110	15432	7.13	0.00000	0.00012	0.00008	0.00050
120	15432	7.78	0.00000	0.00014	0.00009	0.00062
130	15432	8.42	0.00000	0.00014	0.00009	0.00071
140	15432	9.07	0.00001	0.00015	0.00010	0.00076
150	15432	9.72	0.00001	0.00016	0.00010	0.00084
160	15432	10.37	0.00001	0.00017	0.00011	0.00092
170	15432	11.02	0.00002	0.00018	0.00012	0.00102
180	15432	11.66	0.00003	0.00020	0.00012	0.00112
190	15432	12.31	0.00004	0.00022	0.00014	0.00121
200	15432	12.96	0.00004	0.00023	0.00014	0.00133
210	15432	13.61	0.00005	0.00025	0.00015	0.00139
220	15432	14.26	0.00005	0.00026	0.00016	0.00139
230	15432	14.90	0.00006	0.00028	0.00017	0.00139
240	15432	15.55	0.00007	0.00030	0.00017	0.00146
250	15432	16.20	0.00008	0.00032	0.00018	0.00153
260	15432	16.85	0.00009	0.00034	0.00019	0.00166
270	15432	17.50	0.00010	0.00036	0.00020	0.00159
280	15432	18.14	0.00012	0.00039	0.00021	0.00156
290	15432	18.79	0.00014	0.00042	0.00022	0.00159
300	15432	19.44	0.00016	0.00044	0.00024	0.00155
310	15432	20.09	0.00018	0.00049	0.00025	0.00123
320	15432	20.74	0.00020	0.00053	0.00026	0.00106
330	15432	21.38	0.00023	0.00057	0.00028	0.00100
340	15432	22.03	0.00027	0.00062	0.00030	0.00101
350	15432	22.68	0.00030	0.00067	0.00032	0.00105
360	15432	23.33	0.00035	0.00074	0.00034	0.00095
370	15432	23.98	0.00041	0.00082	0.00038	0.00066
380	15432	24.62	0.00047	0.00089	0.00040	0.00037
390	15432	25.27	0.00056	0.00101	0.00045	0.00011
400	15432	25.92	0.00068	0.00112	0.00049	-0.00011

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
410	15432	26.57	0.00074	0.00119	0.00051	-0.00008
420	15432	27.22	0.00087	0.00133	0.00057	0.00008
430	15432	27.86	0.00097	0.00143	0.00062	0.00035
440	15432	28.51	0.00105	0.00154	0.00066	0.00073
450	15432	29.16	0.00119	0.00168	0.00073	0.00148
460	15432	29.81	0.00145	0.00192	0.00084	0.00291
470	15432	30.46	0.00165	0.00212	0.00094	0.00455
480	15432	31.10	0.00185	0.00233	0.00104	0.00195
490	15432	31.75	0.00194	0.00244	0.00110	0.00143
500	15432	32.40	0.00225	0.00274	0.00131	-0.00113
510	15432	33.05	0.00248	0.00305	0.00147	-0.00361
520	15432	33.70	0.00277	0.00336	0.00169	-0.00678
530	15432	34.34	0.00303	0.00364	0.00194	-0.01058
540	15432	34.99	0.00332	0.00404	0.00221	-0.01215
550	15432	35.64	0.00347	0.00430	0.00234	-0.01214
560	15432	36.29	0.00364	0.00448	0.00247	-0.01268
570	15432	36.94	0.00396	0.00479	0.00276	-0.01355
580	15432	37.58	0.00440	0.00520	0.00312	-0.01384
590	15432	38.23	0.00466	0.00533	0.00338	-0.01410
600	15432	38.88	0.00496	0.00615	0.00376	-0.01416
610	15432	39.53	-0.00405	0.00625	0.00453	-0.01520
620	15432	40.18	-0.00704	0.00602	0.00499	-0.01537
610	15432	39.53	0.00307	0.00584	0.00506	-0.01528
600	15432	38.88	0.00603	0.00575	0.00507	-0.01520
610	15432	39.53	0.00629	0.00556	0.00523	-0.01505
620	15432	40.18	0.00655	0.00464	0.00542	-0.01451
630	15432	40.82	0.00683	0.00568	0.00568	-0.01420
640	15432	41.47	0.00698	0.00412	0.00603	-0.01373
630	15432	40.82	0.00251	0.00418	0.00602	-0.01335
620	15432	40.18	0.00147	0.00429	0.00601	-0.01327
610	15432	39.53	0.00132	0.00439	0.00600	-0.01319
600	15432	38.88	0.00670	0.00462	0.00599	-0.01308
610	15432	39.53	0.00714	0.00543	0.00604	-0.01281
620	15432	40.18	0.00731	0.00585	0.00615	-0.01265
630	15432	40.82	0.00757	0.00587	0.00628	-0.01240
640	15432	41.47	0.00771	0.00603	0.00648	-0.01241
650	15432	42.12	0.00778	0.00634	0.00678	-0.01225
640	15432	41.47	0.00782	0.00624	0.00681	-0.01224
630	15432	40.82	0.00336	0.00616	0.00679	-0.01226
620	15432	40.18	0.00157	0.00612	0.00678	-0.01226
610	15432	39.53	0.00053	0.00606	0.00675	-0.01224

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
620	15432	40.18	-0.00267	0.00590	0.00678	-0.01230
630	15432	40.82	-0.00319	0.00592	0.00685	-0.01225
640	15432	41.47	-0.00242	0.00595	0.00694	-0.01217
650	15432	42.12	0.00384	0.00598	0.00716	-0.01181
660	15432	42.77	0.00276	0.00597	0.00743	-0.01150
650	15432	42.12	-0.00235	0.00578	0.00742	-0.01132
660	15432	42.77	-0.00269	0.00569	0.00758	-0.01081
670	15432	43.42	-0.00502	0.00559	0.00784	-0.01053
660	15432	42.77	-0.01367	0.00478	0.00799	-0.00991
650	15432	42.12	-0.02314	0.00494	0.00818	-0.00966

Table A.15: Lateral strain of specimen S1R2

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
0	15089	0.00	-0.00001	-0.00002	-0.00005	-0.00003
10	15089	0.66	0.00000	-0.00003	-0.00006	-0.00005
20	15089	1.33	0.00000	-0.00003	-0.00007	-0.00006
30	15089	1.99	0.00000	-0.00003	-0.00007	-0.00006
40	15089	2.65	0.00001	-0.00004	-0.00008	-0.00005
50	15089	3.31	0.00000	-0.00003	-0.00008	-0.00006
60	15089	3.98	0.00001	-0.00005	-0.00010	-0.00008
70	15089	4.64	0.00001	-0.00006	-0.00011	-0.00011
80	15089	5.30	0.00002	-0.00008	-0.00014	-0.00011
90	15089	5.96	0.00002	-0.00007	-0.00014	-0.00012
100	15089	6.63	0.00003	-0.00008	-0.00014	-0.00012
110	15089	7.29	0.00004	-0.00007	-0.00014	-0.00012
120	15089	7.95	0.00005	-0.00008	-0.00014	-0.00012
130	15089	8.62	0.00007	-0.00007	-0.00014	-0.00010
140	15089	9.28	0.00008	-0.00008	-0.00014	-0.00011
150	15089	9.94	0.00008	-0.00007	-0.00013	-0.00012
160	15089	10.60	0.00011	-0.00008	-0.00014	-0.00010
170	15089	11.27	0.00012	-0.00008	-0.00013	-0.00010
180	15089	11.93	0.00013	-0.00007	-0.00013	-0.00010
190	15089	12.59	0.00015	-0.00007	-0.00013	-0.00009
200	15089	13.25	0.00017	-0.00007	-0.00012	-0.00009
210	15089	13.92	0.00018	-0.00008	-0.00013	-0.00008
220	15089	14.58	0.00018	-0.00007	-0.00013	-0.00008
230	15089	15.24	0.00021	-0.00007	-0.00012	-0.00008
240	15089	15.91	0.00023	-0.00007	-0.00012	-0.00007
250	15089	16.57	0.00025	-0.00006	-0.00012	-0.00005
260	15089	17.23	0.00028	-0.00006	-0.00011	-0.00004
270	15089	17.89	0.00030	-0.00005	-0.00010	-0.00004
280	15089	18.56	0.00032	-0.00004	-0.00009	-0.00002
290	15089	19.22	0.00035	-0.00003	-0.00008	-0.00001
300	15089	19.88	0.00039	-0.00002	-0.00007	0.00002
310	15089	20.54	0.00040	-0.00002	-0.00006	0.00001
320	15089	21.21	0.00044	-0.00001	-0.00004	0.00003
330	15089	21.87	0.00049	0.00001	-0.00003	0.00006
340	15089	22.53	0.00054	0.00003	-0.00001	0.00007
350	15089	23.20	0.00055	0.00005	0.00000	0.00006
360	15089	23.86	0.00059	0.00006	0.00002	0.00008
370	15089	24.52	0.00065	0.00007	0.00004	0.00010
380	15089	25.18	0.00069	0.00010	0.00007	0.00012
390	15089	25.85	0.00076	0.00013	0.00012	0.00016

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
400	15089	26.51	0.00083	0.00014	0.00015	0.00019
410	15089	27.17	0.00090	0.00018	0.00019	0.00022
420	15089	27.83	0.00095	0.00021	0.00023	0.00025
430	15089	28.50	0.00101	0.00024	0.00028	0.00029
440	15089	29.16	0.00084	0.00029	0.00035	0.00033
450	15089	29.82	0.00100	0.00035	0.00041	0.00037
460	15089	30.49	0.00110	0.00041	0.00047	0.00043
470	15089	31.15	0.00124	0.00047	0.00056	0.00051
480	15089	31.81	0.00136	0.00055	0.00068	0.00059
490	15089	32.47	0.00153	0.00062	0.00079	0.00069
500	15089	33.14	0.00209	0.00072	0.00108	0.00086
510	15089	33.80	0.00183	0.00081	0.00132	0.00096
520	15089	34.46	0.00202	0.00131	0.00171	0.00110
530	15089	35.12	0.00150	0.00145	0.00202	0.00120
540	15089	35.79	0.00172	0.00169	0.00254	0.00123
550	15089	36.45	0.00182	0.00182	0.00283	0.00126
560	15089	37.11	0.00197	0.00204	0.00333	0.00131
550	15089	36.45	0.00191	0.00200	0.00360	0.00131
540	15089	35.79	0.00185	0.00186	0.00349	0.00122
530	15089	35.12	0.00181	0.00166	0.00333	0.00112
520	15089	34.46	0.00180	0.00159	0.00326	0.00108
530	15089	35.12	0.00179	0.00154	0.00317	0.00104
540	15089	35.79	0.00181	0.00156	0.00319	0.00105
550	15089	36.45	0.00183	0.00158	0.00323	0.00107
560	15089	37.11	0.00187	0.00164	0.00330	0.00110
570	15089	37.78	0.00194	0.00172	0.00342	0.00115
580	15089	38.44	0.00200	0.00182	0.00358	0.00122
590	15089	39.10	0.00211	0.00201	0.00392	0.00137
600	15089	39.76	0.00223	0.00223	0.00448	0.00155
610	15089	40.43	0.00242	0.00248	0.00511	0.00177
620	15089	41.09	0.00257	0.00267	0.00568	0.00206
630	15089	41.75	0.00265	0.00270	0.00595	0.00220
620	15089	41.09	0.00275	0.00276	0.00633	0.00226
610	15089	40.43	0.00271	0.00266	0.00627	0.00220
600	15089	39.76	0.00266	0.00256	0.00617	0.00220
610	15089	40.43	0.00271	0.00256	0.00611	0.00228
620	15089	41.09	0.00274	0.00263	0.00618	0.00236
630	15089	41.75	0.00281	0.00274	0.00633	0.00246
610	15089	40.43	0.00289	0.00260	0.00611	0.00234
600	15089	39.76	0.00284	0.00248	0.00597	0.00226

Load (kN)	Area	Stress N/mm²	Strain 2			
			Mid	Left	Center	Right
0	15089	0.00	-0.00001	-0.00001	-0.00001	-0.00001
10	15089	0.66	-0.00003	0.00000	-0.00003	-0.00003
20	15089	1.33	-0.00005	0.00000	-0.00003	-0.00004
30	15089	1.99	-0.00006	0.00001	-0.00004	-0.00004
40	15089	2.65	-0.00007	0.00001	-0.00003	-0.00005
50	15089	3.31	-0.00007	0.00002	-0.00003	-0.00005
60	15089	3.98	-0.00007	0.00002	-0.00004	-0.00006
70	15089	4.64	-0.00008	0.00002	-0.00005	-0.00007
80	15089	5.30	-0.00007	0.00002	-0.00005	-0.00007
90	15089	5.96	-0.00007	0.00003	-0.00005	-0.00007
100	15089	6.63	-0.00006	0.00004	-0.00005	-0.00007
110	15089	7.29	-0.00006	0.00003	-0.00005	-0.00007
120	15089	7.95	-0.00006	0.00004	-0.00004	-0.00007
130	15089	8.62	-0.00005	0.00005	-0.00004	-0.00007
140	15089	9.28	-0.00004	0.00006	-0.00003	-0.00006
150	15089	9.94	-0.00003	0.00006	-0.00002	-0.00006
160	15089	10.60	-0.00001	0.00008	-0.00001	-0.00005
170	15089	11.27	-0.00001	0.00009	-0.00001	-0.00005
180	15089	11.93	0.00000	0.00010	-0.00001	-0.00004
190	15089	12.59	0.00001	0.00010	-0.00001	-0.00004
200	15089	13.25	0.00001	0.00012	0.00000	-0.00003
210	15089	13.92	0.00002	0.00013	0.00002	-0.00002
220	15089	14.58	0.00004	0.00015	0.00003	-0.00001
230	15089	15.24	0.00006	0.00016	0.00005	0.00000
240	15089	15.91	0.00007	0.00018	0.00007	0.00001
250	15089	16.57	0.00009	0.00019	0.00009	0.00004
260	15089	17.23	0.00011	0.00022	0.00011	0.00006
270	15089	17.89	0.00014	0.00023	0.00013	0.00008
280	15089	18.56	0.00017	0.00026	0.00016	0.00011
290	15089	19.22	0.00020	0.00029	0.00019	0.00013
300	15089	19.88	0.00024	0.00032	0.00023	0.00017
310	15089	20.54	0.00030	0.00037	0.00030	0.00023
320	15089	21.21	0.00035	0.00040	0.00035	0.00027
330	15089	21.87	0.00042	0.00044	0.00042	0.00034
340	15089	22.53	0.00048	0.00047	0.00050	0.00041
350	15089	23.20	0.00055	0.00050	0.00056	0.00047
360	15089	23.86	0.00065	0.00051	0.00066	0.00057
370	15089	24.52	0.00078	0.00055	0.00083	0.00071
380	15089	25.18	0.00096	0.00054	0.00096	0.00087
390	15089	25.85	0.00120	0.00047	0.00106	0.00104
400	15089	26.51	0.00140	0.00043	0.00115	0.00118

Load (kN)	Area	Stress N/mm²	Strain 2			
			Mid	Left	Center	Right
410	15089	27.17	0.00175	-0.00718	0.00132	0.00140
420	15089	27.83	0.00208	-0.00694	0.00148	0.00161
430	15089	28.50	0.00248	-0.00236	0.00169	0.00184
440	15089	29.16	0.00331	-0.00836	0.00201	0.00158
450	15089	29.82	0.00415	-0.02167	0.00232	-0.00018
460	15089	30.49	0.00486	-0.02689	0.00267	-0.00307
470	15089	31.15	0.00594	-0.02899	0.00303	-0.00508
480	15089	31.81	0.00639	-0.03035	0.00332	-0.00186
490	15089	32.47	0.00716	-0.03233	0.00377	-0.00318
500	15089	33.14	0.00825	-0.03368	0.00421	-0.00191
510	15089	33.80	0.00921	-0.03391	0.00466	-0.00041
520	15089	34.46	0.00968	-0.03390	0.00490	-0.00013
530	15089	35.12	0.01031	-0.03393	0.00551	0.00046
540	15089	35.79	0.01098	-0.03396	0.00638	-0.00100

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	15089	0.00	0.00000	-0.00001	-0.00001	0.00000
10	15089	0.66	0.00000	-0.00003	0.00001	0.00008
20	15089	1.33	0.00000	-0.00005	0.00001	0.00013
30	15089	1.99	-0.00001	-0.00008	0.00004	0.00020
40	15089	2.65	-0.00001	-0.00010	0.00005	0.00023
50	15089	3.31	-0.00001	-0.00015	0.00007	0.00030
60	15089	3.98	-0.00001	-0.00019	0.00009	0.00035
70	15089	4.64	-0.00001	-0.00026	0.00012	0.00044
80	15089	5.30	-0.00001	-0.00031	0.00015	0.00053
90	15089	5.96	-0.00001	-0.00034	0.00016	0.00061
100	15089	6.63	0.00000	-0.00044	0.00021	0.00074
110	15089	7.29	0.00000	-0.00051	0.00024	0.00081
120	15089	7.95	0.00000	-0.00057	0.00026	0.00086
130	15089	8.62	0.00000	-0.00060	0.00028	0.00090
140	15089	9.28	0.00000	-0.00062	0.00031	0.00093
150	15089	9.94	0.00001	-0.00063	0.00035	0.00096
160	15089	10.60	0.00001	-0.00064	0.00040	0.00096
170	15089	11.27	0.00002	-0.00066	0.00044	0.00098
180	15089	11.93	0.00003	-0.00065	0.00051	0.00102
190	15089	12.59	0.00003	-0.00063	0.00062	0.00104
200	15089	13.25	0.00004	-0.00060	0.00073	0.00109
210	15089	13.92	0.00004	-0.00061	0.00081	0.00112
220	15089	14.58	0.00006	-0.00061	0.00090	0.00116
230	15089	15.24	0.00007	-0.00061	0.00100	0.00121
240	15089	15.91	0.00008	-0.00060	0.00112	0.00129
250	15089	16.57	0.00010	-0.00058	0.00123	0.00137
260	15089	17.23	0.00013	-0.00054	0.00133	0.00145
270	15089	17.89	0.00016	-0.00050	0.00142	0.00153
280	15089	18.56	0.00021	-0.00030	0.00153	0.00168
290	15089	19.22	0.00025	-0.00009	0.00157	0.00178
300	15089	19.88	0.00030	0.00001	0.00163	0.00190
310	15089	20.54	0.00033	0.00006	0.00168	0.00201
320	15089	21.21	0.00040	0.00011	0.00176	0.00217
330	15089	21.87	0.00048	0.00015	0.00183	0.00235
340	15089	22.53	0.00061	0.00025	0.00191	0.00255
350	15089	23.20	0.00081	0.00049	0.00201	0.00279
360	15089	23.86	0.00101	0.00047	0.00211	0.00302
370	15089	24.52	0.00121	0.00055	-0.00099	0.00328
380	15089	25.18	0.00135	0.00064	0.00007	0.00346
390	15089	25.85	0.00152	0.00068	0.00228	0.00361
400	15089	26.51	0.00165	0.00068	-0.00244	0.00390

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
410	15089	27.17	0.00174	0.00069	-0.00656	0.00406
420	15089	27.83	0.00212	0.00045	-0.00821	0.00453
430	15089	28.50	0.00242	0.00031	-0.00575	0.00451
440	15089	29.16	0.00342	0.00104	-0.00967	0.00663
450	15089	29.82	0.00423	0.00117	-0.01883	0.00664
460	15089	30.49	0.00487	0.00010	-0.02428	0.00714
470	15089	31.15	0.00591	-0.00204	-0.02176	0.00772
480	15089	31.81	0.00658	-0.00201	-0.03150	0.00866
490	15089	32.47	0.00769	-0.00079	-0.05127	0.00941
500	15089	33.14	0.00820	-0.00173	-0.07718	0.00958
510	15089	33.80	0.01093	-0.00451	-0.05652	0.00770
520	15089	34.46	0.01311	0.00741	-0.05067	0.00762
530	15089	35.12	0.01039	0.05784	-0.04775	0.00746
540	15089	35.79	0.01362	0.05811	-0.03659	0.00840
550	15089	36.45	0.01376	0.05875	-0.01836	0.01051
540	15089	35.79	0.01341	0.05890	-0.00872	0.01038
530	15089	35.12	0.01312	0.05434	-0.00133	0.01010
520	15089	34.46	0.01285	0.05054	0.01224	0.01007
530	15089	35.12	0.01271	0.05954	0.01885	0.00983
540	15089	35.79	0.01270	0.05955	0.01886	0.00983
550	15089	36.45	0.01211	0.05965	0.01927	0.01016

Table A.16: Lateral strain of specimen S2R2

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
0	15089	0.00	0.00001	-0.00001	-0.00001	0.00000
10	15089	0.66	0.00002	-0.00003	-0.00001	0.00000
20	15089	1.33	0.00003	-0.00002	0.00001	0.00000
30	15089	1.99	0.00006	-0.00001	0.00001	0.00000
40	15089	2.65	0.00010	-0.00001	0.00002	0.00000
50	15089	3.31	0.00010	-0.00002	0.00003	-0.00001
60	15089	3.98	0.00011	-0.00005	0.00001	-0.00001
70	15089	4.64	0.00013	-0.00005	0.00001	-0.00001
80	15089	5.30	0.00014	-0.00005	0.00001	-0.00001
90	15089	5.96	0.00017	-0.00004	-0.00001	-0.00002
100	15089	6.63	0.00021	-0.00006	-0.00001	-0.00001
110	15089	7.29	0.00022	-0.00008	-0.00003	-0.00002
120	15089	7.95	0.00025	-0.00009	-0.00004	-0.00003
130	15089	8.62	0.00028	-0.00008	0.00000	-0.00002
140	15089	9.28	0.00029	-0.00008	-0.00002	-0.00002
150	15089	9.94	0.00031	-0.00010	0.00000	-0.00001
160	15089	10.60	0.00033	-0.00015	0.00002	-0.00001
170	15089	11.27	0.00038	-0.00015	0.00004	-0.00001
180	15089	11.93	0.00042	-0.00014	0.00005	-0.00001
190	15089	12.59	0.00045	-0.00014	0.00006	-0.00001
200	15089	13.25	0.00047	-0.00014	0.00003	0.00000
210	15089	13.92	0.00051	-0.00020	0.00005	0.00000
220	15089	14.58	0.00051	-0.00021	0.00005	0.00000
230	15089	15.24	0.00056	-0.00028	0.00006	0.00001
240	15089	15.91	0.00058	-0.00033	0.00006	0.00002
250	15089	16.57	0.00061	-0.00037	0.00006	0.00001
260	15089	17.23	0.00065	-0.00042	0.00006	0.00001
270	15089	17.89	0.00069	-0.00044	0.00010	0.00002
280	15089	18.56	0.00075	-0.00043	0.00011	0.00004
290	15089	19.22	0.00078	-0.00043	0.00014	0.00006
300	15089	19.88	0.00084	-0.00040	0.00016	0.00007
310	15089	20.54	0.00091	-0.00034	0.00020	0.00008
320	15089	21.21	0.00096	-0.00027	0.00022	0.00010
330	15089	21.87	0.00103	-0.00011	0.00023	0.00011
340	15089	22.53	0.00106	-0.00008	0.00024	0.00013
350	15089	23.20	0.00112	-0.00009	0.00026	0.00013
360	15089	23.86	0.00120	0.00005	0.00028	0.00013
370	15089	24.52	0.00123	0.00020	0.00030	0.00015
380	15089	25.18	0.00127	0.00038	0.00032	0.00016
390	15089	25.85	0.00132	0.00045	0.00034	0.00016

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
400	15089	26.51	0.00141	0.00067	0.00038	0.00019
410	15089	27.17	0.00146	0.00079	0.00040	0.00020
420	15089	27.83	0.00153	0.00098	0.00040	0.00021
430	15089	28.50	0.00161	0.00121	0.00046	0.00023
440	15089	29.16	0.00160	0.00166	0.00044	0.00020
450	15089	29.82	0.00165	0.00160	0.00047	0.00022
460	15089	30.49	0.00168	0.00146	0.00049	0.00023
470	15089	31.15	0.00174	0.00101	0.00052	0.00025
480	15089	31.81	0.00180	0.00078	0.00056	0.00027
490	15089	32.47	0.00187	0.00062	0.00063	0.00031
500	15089	33.14	0.00201	0.00193	0.00072	0.00034
510	15089	33.80	0.00212	0.00503	0.00081	0.00014
520	15089	34.46	0.00224	0.00623	0.00088	0.00001
530	15089	35.12	0.00240	0.00770	0.00101	-0.00006
540	15089	35.79	0.00248	0.00869	0.00108	-0.00006
550	15089	36.45	0.00266	0.00991	0.00121	-0.00006
560	15089	37.11	0.00280	0.01393	0.00133	-0.00002
570	15089	37.78	0.00297	0.01438	0.00138	0.00000
580	15089	38.44	0.00311	0.01776	0.00142	-0.00057
590	15089	39.10	0.00329	0.02076	0.00152	0.00006
600	15089	39.76	0.00358	0.02655	0.00168	-0.00136
610	15089	40.43	0.00395	0.02609	0.00179	-0.00148
620	15089	41.09	0.00424	0.02591	0.00188	-0.00623
630	15089	41.75	0.00449	0.02282	0.00195	-0.00896
640	15089	42.42	0.00471	0.02049	0.00205	-0.01027
650	15089	43.08	0.00518	0.01480	0.00207	-0.01070
660	15089	43.74	0.00549	0.01032	0.00217	-0.01434
670	15089	44.40	0.00576	0.00858	0.00221	-0.01320
680	15089	45.07	0.00587	0.00906	0.00228	-0.01254
690	15089	45.73	0.00607	0.00988	-0.00060	-0.01233
700	15089	46.39	0.00662	0.01391	-0.00748	-0.01129
710	15089	47.05	0.00706	0.02101	0.00144	-0.01097
700	15089	46.39	0.00711	0.02269	0.00132	-0.01119
710	15089	47.05	0.00732	0.02618	-0.00118	-0.01331
720	15089	47.72	0.00769	0.02842	-0.01609	-0.01487
730	15089	48.38	0.00844	0.03103	-0.00923	-0.01872
740	15089	49.04	0.00801	0.02934	-0.01065	-0.01923
750	15089	49.71	0.00524	0.01659	-0.01474	-0.03140
760	15089	50.37	0.00531	0.02108	-0.01462	-0.02921
750	15089	49.71	0.00517	0.01924	-0.03217	-0.03009

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
740	15089	49.04	0.00511	0.01900	-0.03408	-0.03027
730	15089	48.38	0.00490	0.01854	-0.03700	-0.03100
720	15089	47.72	0.00470	0.01745	-0.04025	-0.03279
710	15089	47.05	0.00418	0.01583	-0.04264	-0.03978
700	15089	46.39	0.00413	0.01569	-0.04348	-0.04021
710	15089	47.05	0.00414	0.01554	-0.04457	-0.04030
720	15089	47.72	0.00403	0.01441	-0.05410	-0.04055
730	15089	48.38	0.00403	0.01389	-0.06028	-0.04078
740	15089	49.04	0.00406	0.01376	-0.06407	-0.04095
750	15089	49.71	0.00408	0.01374	-0.06569	-0.04081
760	15089	50.37	0.00412	0.01361	-0.06922	-0.03973
770	15089	51.03	0.00418	0.01256	-0.07363	-0.03646
780	15089	51.69	0.00427	0.01168	-0.07085	-0.03314
790	15089	52.36	0.00407	0.01233	-0.07230	-0.03701
800	15089	53.02	0.00432	0.00910	-0.05951	-0.03888

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
0	15089	0.00	0.00000	0.00000	0.00000	0.00000
10	15089	0.66	0.00001	0.00000	0.00000	-0.00001
20	15089	1.33	0.00003	0.00001	0.00000	-0.00001
30	15089	1.99	0.00005	0.00001	0.00001	-0.00001
40	15089	2.65	0.00006	0.00002	0.00001	-0.00001
50	15089	3.31	0.00007	0.00002	0.00001	-0.00001
60	15089	3.98	0.00008	0.00002	0.00000	-0.00002
70	15089	4.64	0.00009	0.00002	0.00000	-0.00002
80	15089	5.30	0.00010	0.00002	0.00000	-0.00003
90	15089	5.96	0.00011	0.00002	0.00000	-0.00003
100	15089	6.63	0.00012	0.00002	0.00000	-0.00004
110	15089	7.29	0.00013	0.00003	0.00000	-0.00004
120	15089	7.95	0.00014	0.00003	0.00000	-0.00005
130	15089	8.62	0.00016	0.00003	0.00000	-0.00004
140	15089	9.28	0.00017	0.00004	0.00001	-0.00005
150	15089	9.94	0.00018	0.00004	0.00001	-0.00004
160	15089	10.60	0.00020	0.00004	0.00001	-0.00004
170	15089	11.27	0.00022	0.00005	0.00002	-0.00004
180	15089	11.93	0.00024	0.00006	0.00002	-0.00003
190	15089	12.59	0.00025	0.00007	0.00002	-0.00003
200	15089	13.25	0.00028	0.00007	0.00003	-0.00002
210	15089	13.92	0.00030	0.00008	0.00004	-0.00001
220	15089	14.58	0.00032	0.00009	0.00004	-0.00001
230	15089	15.24	0.00034	0.00010	0.00005	0.00001
240	15089	15.91	0.00037	0.00012	0.00006	0.00001
250	15089	16.57	0.00040	0.00013	0.00007	0.00002
260	15089	17.23	0.00043	0.00014	0.00008	0.00004
270	15089	17.89	0.00047	0.00015	0.00009	0.00005
280	15089	18.56	0.00051	0.00017	0.00011	0.00007
290	15089	19.22	0.00056	0.00018	0.00012	0.00008
300	15089	19.88	0.00061	0.00021	0.00014	0.00011
310	15089	20.54	0.00065	0.00023	0.00016	0.00012
320	15089	21.21	0.00069	0.00024	0.00017	0.00014
330	15089	21.87	0.00073	0.00027	0.00019	0.00017
340	15089	22.53	0.00078	0.00029	0.00021	0.00019
350	15089	23.20	0.00083	0.00033	0.00023	0.00023
360	15089	23.86	0.00089	0.00036	0.00026	0.00028
370	15089	24.52	0.00094	0.00039	0.00029	0.00032
380	15089	25.18	0.00101	0.00044	0.00032	0.00038
390	15089	25.85	0.00105	0.00047	0.00035	0.00043
400	15089	26.51	0.00112	0.00051	0.00040	0.00051

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
410	15089	27.17	0.00118	0.00055	0.00043	0.00057
420	15089	27.83	0.00126	0.00061	0.00048	0.00066
430	15089	28.50	0.00132	0.00066	0.00052	0.00075
440	15089	29.16	0.00140	0.00072	0.00058	0.00087
450	15089	29.82	0.00149	0.00079	0.00064	0.00099
460	15089	30.49	0.00160	0.00086	0.00070	0.00112
470	15089	31.15	0.00170	0.00093	0.00075	0.00123
480	15089	31.81	0.00180	0.00098	0.00079	0.00133
490	15089	32.47	0.00204	0.00107	0.00087	0.00152
500	15089	33.14	0.00223	0.00119	0.00097	0.00179
510	15089	33.80	0.00241	0.00132	0.00107	0.00207
520	15089	34.46	0.00258	0.00146	0.00117	0.00236
530	15089	35.12	0.00269	0.00154	0.00124	0.00255
540	15089	35.79	0.00286	0.00168	0.00133	0.00282
550	15089	36.45	0.00314	0.00185	0.00145	0.00318
560	15089	37.11	0.00340	0.00204	0.00159	0.00346
570	15089	37.78	0.00358	0.00217	0.00169	0.00369
580	15089	38.44	0.00376	0.00229	0.00178	0.00393
590	15089	39.10	0.00398	0.00247	0.00187	0.00425
600	15089	39.76	0.00424	0.00268	0.00200	0.00462
610	15089	40.43	0.00440	0.00282	0.00194	0.00488
620	15089	41.09	0.00454	0.00292	0.00174	0.00506
630	15089	41.75	0.00470	0.00304	0.00172	0.00527
640	15089	42.42	0.00500	0.00326	0.00163	0.00566
650	15089	43.08	0.00533	0.00351	0.00163	0.00611
660	15089	43.74	0.00550	0.00362	0.00134	0.00629
670	15089	44.40	0.00578	0.00378	0.00139	0.00657
680	15089	45.07	0.00587	0.00384	0.00133	0.00668
690	15089	45.73	0.00604	0.00394	0.00173	0.00684
700	15089	46.39	0.00623	0.00405	0.00177	0.00700
690	15089	45.73	0.00624	0.00407	0.00164	0.00701
680	15089	45.07	0.00620	0.00405	0.00149	0.00697
690	15089	45.73	0.00624	0.00408	0.00152	0.00703
700	15089	46.39	0.00627	0.00409	0.00152	0.00705
710	15089	47.05	0.00635	0.00413	0.00149	0.00711
720	15089	47.72	0.00643	0.00416	0.00156	0.00716
730	15089	48.38	0.00656	0.00420	0.00158	0.00720

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	15089	0.00	0.00001	0.00000	0.00000	0.00000
10	15089	0.66	0.00005	0.00001	0.00003	0.00003
20	15089	1.33	0.00007	0.00002	0.00005	0.00005
30	15089	1.99	0.00010	0.00003	0.00006	0.00006
40	15089	2.65	0.00012	0.00003	0.00007	0.00007
50	15089	3.31	0.00018	0.00003	0.00008	0.00008
60	15089	3.98	0.00022	0.00004	0.00009	0.00009
70	15089	4.64	0.00025	0.00004	0.00011	0.00011
80	15089	5.30	0.00027	0.00006	0.00013	0.00013
90	15089	5.96	0.00031	0.00006	0.00015	0.00015
100	15089	6.63	0.00036	0.00007	0.00017	0.00017
110	15089	7.29	0.00042	0.00008	0.00018	0.00018
120	15089	7.95	0.00048	0.00010	0.00021	0.00020
130	15089	8.62	0.00056	0.00010	0.00022	0.00022
140	15089	9.28	0.00061	0.00011	0.00024	0.00023
150	15089	9.94	0.00072	0.00012	0.00027	0.00026
160	15089	10.60	0.00084	0.00014	0.00030	0.00028
170	15089	11.27	0.00091	0.00015	0.00032	0.00030
180	15089	11.93	0.00100	0.00016	0.00034	0.00033
190	15089	12.59	0.00108	0.00018	0.00037	0.00035
200	15089	13.25	0.00121	0.00019	0.00042	0.00039
210	15089	13.92	0.00132	0.00021	0.00045	0.00041
220	15089	14.58	0.00145	0.00022	0.00048	0.00044
230	15089	15.24	0.00162	0.00024	0.00052	0.00048
240	15089	15.91	0.00177	0.00026	0.00056	0.00050
250	15089	16.57	0.00195	0.00029	0.00062	0.00054
260	15089	17.23	0.00221	0.00030	0.00067	0.00059
270	15089	17.89	0.00244	0.00033	0.00072	0.00063
280	15089	18.56	0.00268	0.00035	0.00078	0.00068
290	15089	19.22	0.00304	0.00038	0.00086	0.00074
300	15089	19.88	0.00329	0.00041	0.00093	0.00080
310	15089	20.54	0.00373	0.00045	0.00102	0.00087
320	15089	21.21	0.00411	0.00048	0.00110	0.00093
330	15089	21.87	0.00464	0.00052	0.00120	0.00101
340	15089	22.53	0.00511	0.00056	0.00130	0.00110
350	15089	23.20	0.00585	0.00061	0.00141	0.00119
360	15089	23.86	0.00695	0.00065	0.00155	0.00131
370	15089	24.52	0.00824	0.00070	0.00169	0.00143
380	15089	25.18	0.00922	0.00074	0.00180	0.00153
390	15089	25.85	0.01026	0.00078	0.00193	0.00163
400	15089	26.51	0.01182	0.00083	0.00207	0.00175

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
410	15089	27.17	0.01346	0.00088	0.00221	0.00188
420	15089	27.83	0.01460	0.00094	0.00235	0.00199
430	15089	28.50	0.01713	0.00101	0.00254	0.00215
440	15089	29.16	0.01984	0.00106	0.00284	0.00242
450	15089	29.82	0.02176	0.00115	0.00314	0.00268
460	15089	30.49	0.02248	0.00128	0.00345	0.00296
470	15089	31.15	0.02256	0.00132	0.00364	0.00311
480	15089	31.81	0.02317	0.00137	0.00393	0.00336
490	15089	32.47	0.02447	0.00152	0.00427	0.00366
500	15089	33.14	0.02576	0.00170	0.00455	0.00388
510	15089	33.80	0.02807	0.00187	0.00487	0.00415
520	15089	34.46	0.02886	0.00201	0.00526	0.00447
530	15089	35.12	0.02979	0.00213	0.00567	0.00478
540	15089	35.79	0.03324	0.00220	0.00598	0.00505
550	15089	36.45	0.03753	0.00220	0.00635	0.00534
560	15089	37.11	0.04161	0.00233	0.00680	0.00569
570	15089	37.78	0.04285	0.00248	0.00729	0.00609
580	15089	38.44	0.04472	0.00262	0.00778	0.00646
590	15089	39.10	0.04589	0.00283	0.00820	0.00678
600	15089	39.76	0.04615	0.00282	0.00860	0.00697
610	15089	40.43	0.04631	0.00275	0.00886	0.00718
620	15089	41.09	0.04655	0.00281	0.00927	0.00746
630	15089	41.75	0.04678	0.00299	0.00971	-
640	15089	42.42	0.04696	0.00308	0.01029	-
650	15089	43.08	0.04737	0.00345	0.01120	-
660	15089	43.74	0.04764	0.00373	0.01178	-
670	15089	44.40	0.04795	0.00394	0.01242	-
680	15089	45.07	0.04812	0.00415	0.01277	-
690	15089	45.73	0.04833	0.00457	0.01310	-
700	15089	46.39	0.04877	0.00504	0.01390	-
690	15089	45.73	0.04879	0.00513	0.01389	-
680	15089	45.07	0.04878	0.00529	0.01381	-
670	15089	44.40	0.04876	0.00564	0.01370	-
680	15089	45.07	0.04882	0.00576	0.01380	-
690	15089	45.73	0.04886	0.00579	0.01389	-
700	15089	46.39	0.04896	0.00591	0.01405	-
710	15089	47.05	0.04919	0.00616	0.01454	-
720	15089	47.72	0.04946	0.00684	0.01522	-
730	15089	48.38	0.04957	0.00702	0.01552	-
740	15089	49.04	0.04984	0.00734	0.01617	-
730	15089	48.38	0.04982	0.00737	0.01604	-

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
720	15089	47.72	0.04978	0.00730	0.01587	-
710	15089	47.05	0.04964	0.00716	0.01550	-
700	15089	46.39	0.04954	0.00719	0.01553	-

Table A.17: Lateral strain of specimen S1R3

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
0	14573	0.00	-0.00001	-0.00001	-0.00001	-0.00001
10	14573	0.69	-0.00001	0.00000	0.00000	0.00001
20	14573	1.37	-0.00002	0.00001	0.00000	0.00000
30	14573	2.06	-0.00002	0.00001	0.00001	0.00000
40	14573	2.74	-0.00003	0.00001	0.00001	0.00000
50	14573	3.43	-0.00003	0.00001	0.00001	0.00000
60	14573	4.12	-0.00004	0.00001	0.00001	0.00000
70	14573	4.80	-0.00005	0.00000	0.00001	0.00000
80	14573	5.49	-0.00005	0.00001	0.00002	-0.00001
90	14573	6.18	-0.00006	0.00001	0.00001	0.00001
100	14573	6.86	-0.00006	0.00001	0.00002	-0.00001
110	14573	7.55	-0.00007	0.00001	0.00002	0.00001
120	14573	8.23	-0.00008	0.00001	0.00002	0.00000
130	14573	8.92	-0.00008	0.00001	0.00002	0.00001
140	14573	9.61	-0.00009	0.00002	0.00002	0.00001
150	14573	10.29	-0.00009	0.00002	0.00004	-0.00001
160	14573	10.98	-0.00009	0.00002	0.00003	0.00000
170	14573	11.67	-0.00010	0.00002	0.00003	0.00000
180	14573	12.35	-0.00011	0.00003	0.00004	0.00000
190	14573	13.04	-0.00011	0.00003	0.00004	0.00000
200	14573	13.72	-0.00012	0.00004	0.00005	0.00001
210	14573	14.41	-0.00013	0.00005	0.00005	0.00001
220	14573	15.10	-0.00013	0.00005	0.00006	0.00000
230	14573	15.78	-0.00012	0.00006	0.00006	0.00001
240	14573	16.47	-0.00013	0.00007	0.00007	0.00001
250	14573	17.16	-0.00012	0.00007	0.00008	0.00002
260	14573	17.84	-0.00012	0.00009	0.00009	0.00003
270	14573	18.53	-0.00012	0.00011	0.00009	0.00004
280	14573	19.21	-0.00010	0.00012	0.00011	0.00004
290	14573	19.90	-0.00010	0.00013	0.00011	0.00005
300	14573	20.59	-0.00009	0.00014	0.00011	0.00006
310	14573	21.27	-0.00008	0.00015	0.00013	0.00008
320	14573	21.96	-0.00007	0.00017	0.00013	0.00010
330	14573	22.64	-0.00007	0.00018	0.00014	0.00012
340	14573	23.33	-0.00005	0.00020	0.00016	0.00014
350	14573	24.02	-0.00003	0.00022	0.00018	0.00016
360	14573	24.70	-0.00001	0.00025	0.00019	0.00019
370	14573	25.39	0.00002	0.00027	0.00020	0.00022
380	14573	26.08	0.00007	0.00030	0.00023	0.00027
390	14573	26.76	0.00009	0.00033	0.00025	0.00031

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
400	14573	27.45	0.00013	0.00036	0.00027	0.00031
410	14573	28.13	0.00018	0.00039	0.00030	0.00034
420	14573	28.82	0.00022	0.00041	0.00032	0.00038
430	14573	29.51	0.00028	0.00047	0.00035	0.00044
440	14573	30.19	0.00036	0.00053	0.00040	0.00049
450	14573	30.88	0.00055	0.00068	0.00050	0.00063
460	14573	31.57	0.00088	0.00088	0.00067	0.00086
470	14573	32.25	0.00107	0.00104	0.00080	0.00106
480	14573	32.94	0.00123	0.00118	0.00091	0.00127
490	14573	33.62	0.00116	0.00112	0.00097	0.00147
500	14573	34.31	0.00122	0.00120	0.00102	0.00161
510	14573	35.00	0.00135	0.00128	0.00110	0.00178
520	14573	35.68	0.00142	0.00133	0.00114	0.00190
530	14573	36.37	0.00152	0.00138	0.00120	0.00204
540	14573	37.05	0.00147	0.00132	0.00120	0.00220
550	14573	37.74	0.00151	0.00132	0.00120	0.00231
560	14573	38.43	0.00148	0.00124	0.00116	0.00246

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
0	14573	0.00	-0.00001	0.00000	0.00001	0.00006
10	14573	0.69	-0.00001	0.00000	0.00000	0.00009
20	14573	1.37	-0.00001	0.00000	-0.00001	0.00013
30	14573	2.06	-0.00001	0.00000	0.00000	0.00021
40	14573	2.74	-0.00002	-0.00001	-0.00001	0.00024
50	14573	3.43	-0.00002	0.00000	0.00000	0.00026
60	14573	4.12	-0.00005	-0.00002	-0.00002	0.00077
70	14573	4.80	-0.00005	-0.00002	-0.00002	0.00089
80	14573	5.49	-0.00006	-0.00002	-0.00002	0.00095
90	14573	6.18	-0.00007	-0.00002	-0.00003	0.00102
100	14573	6.86	-0.00008	-0.00002	-0.00003	0.00110
110	14573	7.55	-0.00008	-0.00001	-0.00003	0.00115
120	14573	8.23	-0.00008	-0.00001	-0.00002	0.00120
130	14573	8.92	-0.00008	0.00000	-0.00002	0.00122
140	14573	9.61	-0.00008	0.00000	-0.00001	0.00126
150	14573	10.29	-0.00007	0.00000	-0.00001	0.00130
160	14573	10.98	-0.00007	0.00000	-0.00001	0.00135
170	14573	11.67	-0.00007	0.00000	-0.00002	0.00141
180	14573	12.35	-0.00007	0.00001	-0.00001	0.00146
190	14573	13.04	-0.00007	0.00001	0.00000	0.00150
200	14573	13.72	-0.00006	0.00001	-0.00001	0.00156
210	14573	14.41	-0.00007	0.00001	-0.00001	0.00163
220	14573	15.10	-0.00006	0.00001	-0.00001	0.00163
230	14573	15.78	-0.00007	0.00002	0.00000	0.00164
240	14573	16.47	-0.00006	0.00001	-0.00001	0.00168
250	14573	17.16	-0.00006	0.00002	0.00000	0.00168
260	14573	17.84	-0.00005	0.00002	0.00000	0.00171
270	14573	18.53	-0.00005	0.00002	0.00001	0.00169
280	14573	19.21	-0.00005	0.00003	0.00001	0.00170
290	14573	19.90	-0.00004	0.00003	0.00001	0.00170
300	14573	20.59	-0.00004	0.00004	0.00002	0.00174
310	14573	21.27	-0.00004	0.00005	0.00002	0.00176
320	14573	21.96	-0.00002	0.00005	0.00002	0.00178
330	14573	22.64	-0.00002	0.00005	0.00003	0.00181
340	14573	23.33	-0.00002	0.00006	0.00004	0.00183
350	14573	24.02	-0.00001	0.00007	0.00005	0.00190
360	14573	24.70	0.00000	0.00008	0.00005	0.00193
370	14573	25.39	0.00002	0.00009	0.00007	0.00193
380	14573	26.08	0.00003	0.00010	0.00008	0.00195
390	14573	26.76	0.00004	0.00011	0.00010	0.00189
400	14573	27.45	0.00007	0.00013	0.00012	0.00190

Load (kN)	Area	Stress N/mm²	Strain 2			
			Mid	Left	Center	Right
410	14573	28.13	0.00009	0.00015	0.00014	0.00186
420	14573	28.82	0.00011	0.00019	0.00017	0.00190
430	14573	29.51	0.00014	0.00021	0.00020	0.00194
440	14573	30.19	0.00019	0.00025	0.00025	0.00199
450	14573	30.88	0.00023	0.00029	0.00032	0.00203
460	14573	31.57	0.00029	0.00035	0.00042	0.00208
470	14573	32.25	0.00038	0.00040	0.00054	0.00220
480	14573	32.94	0.00045	0.00046	0.00066	0.00226
490	14573	33.62	0.00054	0.00053	0.00081	0.00250
500	14573	34.31	0.00069	0.00061	0.00111	0.00267
510	14573	35.00	0.00084	0.00067	0.00133	0.00263
520	14573	35.68	0.00101	0.00060	0.00155	0.00270
530	14573	36.37	0.00108	0.00031	0.00161	0.00266
540	14573	37.05	0.00124	0.00013	0.00194	0.00291
550	14573	37.74	0.00133	0.00004	0.00205	0.00295
560	14573	38.43	0.00150	0.00001	0.00225	0.00308
570	14573	39.11	0.00143	0.00000	0.00237	0.00316
580	14573	39.80	0.00127	-0.00004	0.00257	0.00355
590	14573	40.49	0.00124	-0.00019	0.00262	0.00469
600	14573	41.17	0.00131	-0.00017	0.00292	0.00700
590	14573	40.49	0.00107	0.00003	0.00275	0.00898
580	14573	39.80	0.00100	-0.00001	0.00264	0.00957
570	14573	39.11	0.00091	-0.00004	0.00252	0.01020
580	14573	39.80	0.00091	-0.00003	0.00254	0.01022
590	14573	40.49	0.00091	-0.00002	0.00255	0.01021

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	14573	0.00	0.00000	0.00000	0.00000	0.00000
10	14573	0.69	0.00001	0.00002	0.00002	0.00003
20	14573	1.37	0.00002	0.00003	0.00003	0.00006
30	14573	2.06	0.00004	0.00004	0.00004	0.00009
40	14573	2.74	0.00005	0.00005	0.00005	0.00012
50	14573	3.43	0.00006	0.00006	0.00006	0.00013
60	14573	4.12	0.00005	0.00007	0.00006	0.00014
70	14573	4.80	0.00006	0.00008	0.00007	0.00017
80	14573	5.49	0.00007	0.00008	0.00008	0.00020
90	14573	6.18	0.00007	0.00009	0.00009	0.00021
100	14573	6.86	0.00008	0.00010	0.00010	0.00023
110	14573	7.55	0.00008	0.00011	0.00010	0.00025
120	14573	8.23	0.00009	0.00011	0.00011	0.00027
130	14573	8.92	0.00010	0.00012	0.00012	0.00030
140	14573	9.61	0.00011	0.00013	0.00013	0.00032
150	14573	10.29	0.00012	0.00014	0.00014	0.00035
160	14573	10.98	0.00013	0.00015	0.00015	0.00037
170	14573	11.67	0.00014	0.00016	0.00016	0.00039
180	14573	12.35	0.00015	0.00017	0.00017	0.00042
190	14573	13.04	0.00016	0.00018	0.00017	0.00043
200	14573	13.72	0.00017	0.00019	0.00018	0.00045
210	14573	14.41	0.00018	0.00019	0.00019	0.00047
220	14573	15.10	0.00019	0.00020	0.00019	0.00049
230	14573	15.78	0.00021	0.00020	0.00020	0.00051
240	14573	16.47	0.00022	0.00021	0.00020	0.00052
250	14573	17.16	0.00024	0.00022	0.00021	0.00056
260	14573	17.84	0.00026	0.00022	0.00021	0.00057
270	14573	18.53	0.00030	0.00024	0.00022	0.00061
280	14573	19.21	0.00033	0.00025	0.00024	0.00065
290	14573	19.90	0.00039	0.00029	0.00024	0.00071
300	14573	20.59	0.00045	0.00031	0.00026	0.00076
310	14573	21.27	0.00051	0.00034	0.00027	0.00082
320	14573	21.96	0.00073	0.00042	0.00031	0.00104
330	14573	22.64	0.00072	0.00043	0.00031	0.00104
340	14573	23.33	0.00085	0.00047	0.00035	0.00117
350	14573	24.02	0.00095	0.00051	0.00037	0.00130
360	14573	24.70	0.00113	0.00061	0.00041	0.00164
370	14573	25.39	0.00125	0.00068	0.00045	0.00188
380	14573	26.08	0.00143	0.00080	0.00051	0.00232
390	14573	26.76	0.00157	0.00090	0.00056	0.00271
400	14573	27.45	0.00176	0.00102	0.00062	0.00318

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
410	14573	28.13	0.00214	0.00128	0.00072	0.00417
420	14573	28.82	0.00240	0.00147	0.00080	0.00479
430	14573	29.51	0.00254	0.00172	0.00091	0.00540
440	14573	30.19	0.00274	0.00189	0.00104	0.00599
450	14573	30.88	0.00334	0.00242	0.00143	0.00761
460	14573	31.57	0.00430	0.00320	0.00206	0.00964
470	14573	32.25	0.00499	0.00288	0.00245	0.01097
480	14573	32.94	0.00550	0.00320	0.00277	0.01192
490	14573	33.62	0.00608	0.00356	0.00323	0.01297
500	14573	34.31	0.00697	0.00413	0.00398	0.01472

Table A.18: Lateral strain of specimen S2R3

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
0	14573	0.00	0.00000	-0.00001	0.00000	0.00000
10	14573	0.69	0.00001	-0.00001	0.00000	0.00000
20	14573	1.37	0.00002	-0.00001	0.00000	0.00000
30	14573	2.06	0.00004	-0.00002	0.00001	0.00000
40	14573	2.74	0.00004	-0.00002	0.00001	0.00000
50	14573	3.43	0.00005	-0.00002	0.00001	0.00000
60	14573	4.12	0.00004	-0.00005	0.00000	0.00000
70	14573	4.80	0.00003	-0.00007	-0.00002	-0.00001
80	14573	5.49	0.00005	-0.00008	-0.00002	-0.00001
90	14573	6.18	0.00005	-0.00008	-0.00002	-0.00001
100	14573	6.86	0.00007	-0.00008	-0.00002	-0.00001
110	14573	7.55	0.00009	-0.00008	-0.00002	-0.00001
120	14573	8.23	0.00010	-0.00009	-0.00001	-0.00001
130	14573	8.92	0.00012	-0.00010	-0.00001	-0.00001
140	14573	9.61	0.00012	-0.00011	-0.00002	-0.00001
150	14573	10.29	0.00013	-0.00011	-0.00001	-0.00001
160	14573	10.98	0.00015	-0.00012	-0.00001	0.00000
170	14573	11.67	0.00017	-0.00012	0.00000	0.00000
180	14573	12.35	0.00019	-0.00013	0.00000	0.00000
190	14573	13.04	0.00020	-0.00014	0.00001	0.00000
200	14573	13.72	0.00016	-0.00019	0.00004	0.01283
210	14573	14.41	0.00017	-0.00020	0.00004	0.01304
220	14573	15.10	0.00019	-0.00021	0.00005	0.01302
230	14573	15.78	0.00022	-0.00022	0.00006	0.01292
240	14573	16.47	0.00024	-0.00023	0.00007	0.01283
250	14573	17.16	0.00027	-0.00025	0.00008	0.01268
260	14573	17.84	0.00033	-0.00026	0.00009	0.01239
270	14573	18.53	0.00038	-0.00028	0.00011	0.01218
280	14573	19.21	0.00042	-0.00030	0.00012	0.01204
290	14573	19.90	0.00047	-0.00031	0.00013	0.01194
300	14573	20.59	0.00054	-0.00033	0.00015	0.01184
310	14573	21.27	0.00061	-0.00035	0.00017	0.01174
320	14573	21.96	0.00068	-0.00036	0.00019	0.01168
330	14573	22.64	0.00080	-0.00038	0.00021	0.01163
340	14573	23.33	0.00089	-0.00040	0.00023	0.01153
350	14573	24.02	0.00102	-0.00042	0.00027	0.01149
360	14573	24.70	0.00112	-0.00043	0.00030	0.01146
370	14573	25.39	0.00123	-0.00044	0.00032	0.01146
380	14573	26.08	0.00135	-0.00045	0.00035	0.01145
390	14573	26.76	0.00153	-0.00047	0.00039	0.01142

Load (kN)	Area	Stress N/mm²	Strain			
			1			
			Mid	Left	Center	Right
400	14573	27.45	0.00172	-0.00049	0.00042	0.01142
410	14573	28.13	0.00205	-0.00049	0.00045	0.01137
420	14573	28.82	0.00249	-0.00050	0.00050	0.01137
430	14573	29.51	0.00282	-0.00049	0.00052	0.01138
440	14573	30.19	0.00306	-0.00048	0.00054	0.01138
450	14573	30.88	0.00351	-0.00048	0.00058	0.01140
460	14573	31.57	0.00406	-0.00048	0.00064	0.01142
470	14573	32.25	0.00423	-0.00076	0.00068	0.01144
480	14573	32.94	0.00443	-0.00248	0.00074	0.01148
490	14573	33.62	0.00468	-0.00097	0.00082	0.01153
500	14573	34.31	0.00506	-0.00199	0.00088	0.01156
510	14573	35.00	0.00537	-0.00141	0.00093	0.01161
520	14573	35.68	0.00536	-0.00131	0.00097	0.01159
530	14573	36.37	0.00564	-0.00123	0.00101	0.01163
540	14573	37.05	0.00593	-0.00119	0.00103	0.01165
550	14573	37.74	0.00612	-0.00116	0.00105	0.01166
560	14573	38.43	0.00648	-0.00087	0.00107	0.01167
570	14573	39.11	0.00592	-0.00137	0.00108	0.01165
580	14573	39.80	0.00546	-0.00982	0.00111	0.01152
590	14573	40.49	0.00551	-0.01012	0.00111	0.01148
600	14573	41.17	0.00575	-0.00312	0.00112	0.01137
610	14573	41.86	0.00586	0.00084	0.00110	0.01129
620	14573	42.54	0.00562	0.00106	0.00108	0.01127
630	14573	43.23	0.00533	0.00146	0.00101	0.01123
640	14573	43.92	0.00517	0.00165	0.00098	0.01125
650	14573	44.60	0.00539	0.00209	0.00090	0.01136
660	14573	45.29	0.00560	0.00315	0.00076	-
670	14573	45.98	0.00557	0.00476	0.00062	-
680	14573	46.66	0.00536	0.00647	0.00060	0.18546

Load (kN)	Area	Stress N/mm²	Strain			
			2			
			Mid	Left	Center	Right
0	14573	0.00	0.00000	0.00000	0.00000	0.00000
10	14573	0.69	0.00001	0.00000	-0.00003	-0.00002
20	14573	1.37	0.00001	0.00000	-0.00003	-0.00002
30	14573	2.06	0.00001	0.00000	-0.00003	-0.00003
40	14573	2.74	0.00002	0.00000	-0.00003	-0.00004
50	14573	3.43	0.00002	0.00000	-0.00003	-0.00008
60	14573	4.12	0.00003	0.00001	-0.00004	-0.00010
70	14573	4.80	0.00003	0.00002	-0.00004	-0.00011
80	14573	5.49	0.00004	0.00002	-0.00004	-0.00013
90	14573	6.18	0.00005	0.00002	-0.00003	-0.00011
100	14573	6.86	0.00006	0.00002	-0.00003	-0.00004
110	14573	7.55	0.00006	0.00003	-0.00003	0.00006
120	14573	8.23	0.00007	0.00003	-0.00003	0.00019
130	14573	8.92	0.00008	0.00004	-0.00003	0.00039
140	14573	9.61	0.00009	0.00003	-0.00003	0.00059
150	14573	10.29	0.00011	0.00004	-0.00003	0.00093
160	14573	10.98	0.00012	0.00005	-0.00003	0.00114
170	14573	11.67	0.00013	0.00005	-0.00002	0.00132
180	14573	12.35	0.00014	0.00006	-0.00002	0.00156
190	14573	13.04	0.00015	0.00006	-0.00002	0.00172
200	14573	13.72	0.00017	0.00007	-0.00001	0.00217
210	14573	14.41	0.00019	0.00008	-0.00001	0.00250
220	14573	15.10	0.00020	0.00008	-0.00001	0.00269
230	14573	15.78	0.00022	0.00009	-0.00001	0.00275
240	14573	16.47	0.00023	0.00010	-0.00001	0.00281
250	14573	17.16	0.00025	0.00011	0.00000	0.00288
260	14573	17.84	0.00027	0.00012	0.00000	0.00309
270	14573	18.53	0.00029	0.00012	0.00000	0.00318
280	14573	19.21	0.00031	0.00013	0.00000	0.00324
290	14573	19.90	0.00033	0.00015	0.00001	0.00333
300	14573	20.59	0.00035	0.00016	0.00001	0.00345
310	14573	21.27	0.00038	0.00017	0.00002	0.00352
320	14573	21.96	0.00040	0.00018	0.00002	0.00356
330	14573	22.64	0.00042	0.00019	0.00003	0.00362
340	14573	23.33	0.00046	0.00022	0.00004	0.00371
350	14573	24.02	0.00050	0.00024	0.00005	0.00381
360	14573	24.70	0.00054	0.00026	0.00006	0.00388
370	14573	25.39	0.00058	0.00028	0.00006	0.00395
380	14573	26.08	0.00063	0.00030	0.00008	0.00403
390	14573	26.76	0.00066	0.00032	0.00009	0.00408
400	14573	27.45	0.00071	0.00036	0.00010	0.00417

Load (kN)	Area	Stress N/mm²	Strain 2 Mid	Left	Center	Right
410	14573	28.13	0.00076	0.00039	0.00012	0.00414
420	14573	28.82	0.00082	0.00042	0.00014	0.00275
430	14573	29.51	0.00086	0.00045	0.00016	0.00338
440	14573	30.19	0.00091	0.00048	0.00017	0.00244
450	14573	30.88	0.00099	0.00051	0.00020	0.00356
460	14573	31.57	0.00110	0.00057	0.00023	0.00353
470	14573	32.25	0.00121	0.00062	0.00025	0.00288
480	14573	32.94	0.00133	0.00068	0.00028	0.00189
490	14573	33.62	0.00145	0.00075	0.00033	0.00170
500	14573	34.31	0.00162	0.00085	0.00042	0.00036
510	14573	35.00	0.00182	0.00096	0.00055	0.00097
520	14573	35.68	0.00198	0.00104	0.00066	0.00095
530	14573	36.37	0.00217	0.00114	0.00081	0.00040
540	14573	37.05	0.00245	0.00129	0.00097	0.00048
550	14573	37.74	0.00270	0.00142	0.00110	-0.00076
560	14573	38.43	0.00293	0.00154	0.00123	-0.00164
570	14573	39.11	0.00315	0.00166	0.00136	-0.00038
580	14573	39.80	0.00337	0.00177	0.00148	-0.00057
590	14573	40.49	0.00365	0.00190	0.00161	-0.00222
600	14573	41.17	0.00385	0.00198	0.00169	0.00017
610	14573	41.86	0.00401	0.00204	0.00175	0.00018
620	14573	42.54	0.00424	0.00213	0.00185	0.00130
630	14573	43.23	0.00443	0.00220	0.00193	-0.00077
640	14573	43.92	0.00457	0.00225	0.00199	-0.00125
650	14573	44.60	0.00486	0.00239	0.00214	0.00135
660	14573	45.29	0.00493	0.00241	0.00217	0.00150
670	14573	45.98	0.00500	0.00244	0.00219	0.00173
680	14573	46.66	0.00511	0.00249	0.00224	0.00204
670	14573	45.98	0.00508	0.00248	0.00223	0.00174
660	14573	45.29	0.00507	0.00248	0.00223	0.00174
650	14573	44.60	0.00505	0.00248	0.00223	0.00142
660	14573	45.29	0.00507	0.00249	0.00224	0.00118
670	14573	45.98	0.00510	0.00250	0.00225	0.00119
680	14573	46.66	0.00514	0.00251	0.00226	-0.00030
670	14573	45.98	0.00512	0.00252	0.00226	-0.00012

Load (kN)	Area	Stress N/mm²	Strain			
			3			
			Mid	Left	Center	Right
0	14573	0.00	0.00000	0.00000	0.00000	0.00000
10	14573	0.69	0.00001	0.00000	0.00001	0.00002
20	14573	1.37	0.00002	0.00001	0.00001	0.00003
30	14573	2.06	0.00003	0.00002	0.00002	0.00005
40	14573	2.74	0.00003	0.00002	0.00002	0.00006
50	14573	3.43	0.00004	0.00003	0.00002	0.00007
60	14573	4.12	0.00005	0.00004	0.00003	0.00008
70	14573	4.80	0.00006	0.00004	0.00004	0.00009
80	14573	5.49	0.00007	0.00005	0.00005	0.00011
90	14573	6.18	0.00008	0.00006	0.00006	0.00012
100	14573	6.86	0.00009	0.00008	0.00007	0.00014
110	14573	7.55	0.00010	0.00009	0.00008	0.00017
120	14573	8.23	0.00011	0.00010	0.00010	0.00018
130	14573	8.92	0.00013	0.00012	0.00011	0.00020
140	14573	9.61	0.00014	0.00013	0.00012	0.00022
150	14573	10.29	0.00015	0.00015	0.00015	0.00024
160	14573	10.98	0.00018	0.00017	0.00017	0.00026
170	14573	11.67	0.00019	0.00019	0.00020	0.00029
180	14573	12.35	0.00021	0.00021	0.00022	0.00031
190	14573	13.04	0.00023	0.00023	0.00024	0.00034
200	14573	13.72	0.00026	0.00026	0.00028	0.00038
210	14573	14.41	0.00028	0.00029	0.00031	0.00041
220	14573	15.10	0.00030	0.00032	0.00034	0.00045
230	14573	15.78	0.00032	0.00035	0.00037	0.00048
240	14573	16.47	0.00035	0.00038	0.00042	0.00053
250	14573	17.16	0.00039	0.00043	0.00047	0.00058
260	14573	17.84	0.00041	0.00047	0.00051	0.00062
270	14573	18.53	0.00046	0.00053	0.00057	0.00070
280	14573	19.21	0.00050	0.00059	0.00062	0.00077
290	14573	19.90	0.00052	0.00063	0.00067	0.00082
300	14573	20.59	0.00055	0.00069	0.00072	0.00089
310	14573	21.27	0.00059	0.00075	0.00079	0.00096
320	14573	21.96	0.00063	0.00082	0.00086	0.00105
330	14573	22.64	0.00069	0.00091	0.00094	0.00115
340	14573	23.33	0.00073	0.00098	0.00100	0.00123
350	14573	24.02	0.00077	0.00104	0.00106	0.00132
360	14573	24.70	0.00082	0.00113	0.00114	0.00142
370	14573	25.39	0.00088	0.00125	0.00122	0.00153
380	14573	26.08	0.00092	0.00132	0.00126	0.00163
390	14573	26.76	0.00098	0.00142	0.00135	0.00178
400	14573	27.45	0.00111	0.00164	0.00154	0.00205

Load (kN)	Area	Stress N/mm²	Strain 3			
			Mid	Left	Center	Right
410	14573	28.13	0.00128	0.00190	0.00174	0.00239
420	14573	28.82	0.00137	0.00204	0.00186	0.00258
430	14573	29.51	0.00147	0.00219	0.00197	0.00279
440	14573	30.19	0.00159	0.00237	0.00212	0.00304
450	14573	30.88	0.00177	0.00261	0.00229	0.00335
460	14573	31.57	0.00195	0.00285	0.00247	0.00369
470	14573	32.25	0.00219	0.00314	0.00281	0.00359
480	14573	32.94	0.00236	0.00341	0.00302	0.00410
490	14573	33.62	0.00248	0.00364	0.00320	0.00406
500	14573	34.31	0.00262	0.00405	0.00348	0.00253
510	14573	35.00	0.00275	0.00450	0.00376	0.00373
520	14573	35.68	0.00292	0.00494	0.00410	0.00536
530	14573	36.37	0.00308	0.00533	0.00452	0.00282
540	14573	37.05	0.00333	0.00610	0.00517	0.00410
550	14573	37.74	0.00345	0.00638	0.00542	0.00320
560	14573	38.43	0.00365	0.00697	0.00592	0.00672
570	14573	39.11	0.00381	0.00737	0.00631	0.00747
580	14573	39.80	0.00393	0.00759	0.00655	0.00774
590	14573	40.49	0.00388	0.00792	0.00702	0.00737
600	14573	41.17	0.00409	0.00861	0.00756	0.00599
590	14573	40.49	0.00407	0.00849	0.00797	0.00533
580	14573	39.80	0.00407	0.00843	0.00818	0.00518
590	14573	40.49	0.00412	0.00786	0.00862	0.00479
600	14573	41.17	0.00418	0.00791	0.00878	0.00481
610	14573	41.86	0.00435	0.00805	0.00927	0.00479
620	14573	42.54	0.00452	0.00817	0.00953	0.00360
630	14573	43.23	0.00467	0.00842	0.00974	0.00457
620	14573	42.54	0.00482	0.00822	0.00778	0.00702
610	14573	41.86	0.00484	0.00803	0.00749	0.00745
620	14573	42.54	0.00502	0.00692	0.00618	0.00884
630	14573	43.23	0.00513	0.00701	0.00584	0.00945

Appendix B

List of Papers Communicated

- Sushil S. Sharma, Dr. Urmil V. Dave and Shri Himat Solanki, "FRP wrapping for RC columns with varying corner radius", 8th Biennial Conference (SEC), SVNIT, Surat, India, 19-21 December 2012. (Abstract Communicated)
- Sushil S. Sharma, Dr. Urmil V. Dave and Shri Himat Solanki, "Effect of corner radius on the behaviour of GFRP-confined square RC columns", 3rd International Con- ference, NUiCONE - 2012, Departmet of Civil Engineering, Nirma University, Ahmedabad, 6 - 8 December 2012. (Abstract Communicated)