LECTURE - 37

CASE STUDIES ON RETROFITTING AND REHABILITATION

<u>RETROFITTING:</u>

- The addition of new technology or features to older systems and improving the structures with energy efficiency or the process of strengthening existing structural components in order to make them resistant.

<u>REHABILITATION:</u>

- reconstruction of the structural components which were damaged.

DAMAGED PILES

Problems of Concrete Piles

- ✓ Loss of reinforcement due to corrosion
- ✓ Lack of confinement in concrete and
- ✓ Deterioration of concrete due to attack of multiple environmental agencies

Rehabilitation Methods

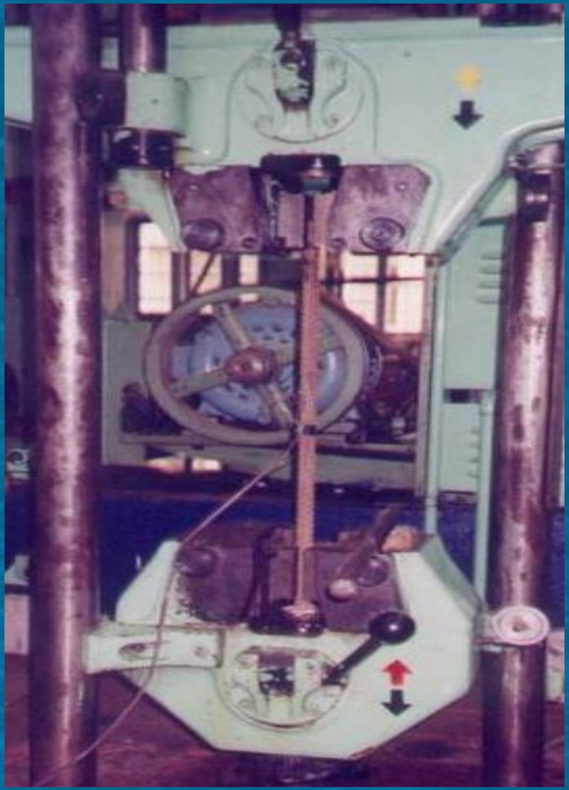
- ✓ Concrete jacketing
- ✓ Steel jacketing
- ✓ FRP wrapping

Wrapping RC Pile with GFRP Composite

OBJECTIVE AND SCOPE

- Objective:
  - The main objective is to study the behaviour of concrete piles wrapped with GFRP composites and to develop guidelines for retrofitting and rehabilitation of piles.
- Scope:
  - Test control pile specimens upto failure
  - Retrofit concrete piles with GFRP fabric
  - Test the retrofitted concrete piles under monotonic lateral load with and without axial compressive loads
  - Test the concrete piles upto the first flexural crack
  - Rehabilitate the cracked piles with GFRP wrapping
  - Study the behavior of retrofitted piles using ansys and
  - Develop guidelines for retrofitting and rehabilitation of concrete piles using GFRP composists.

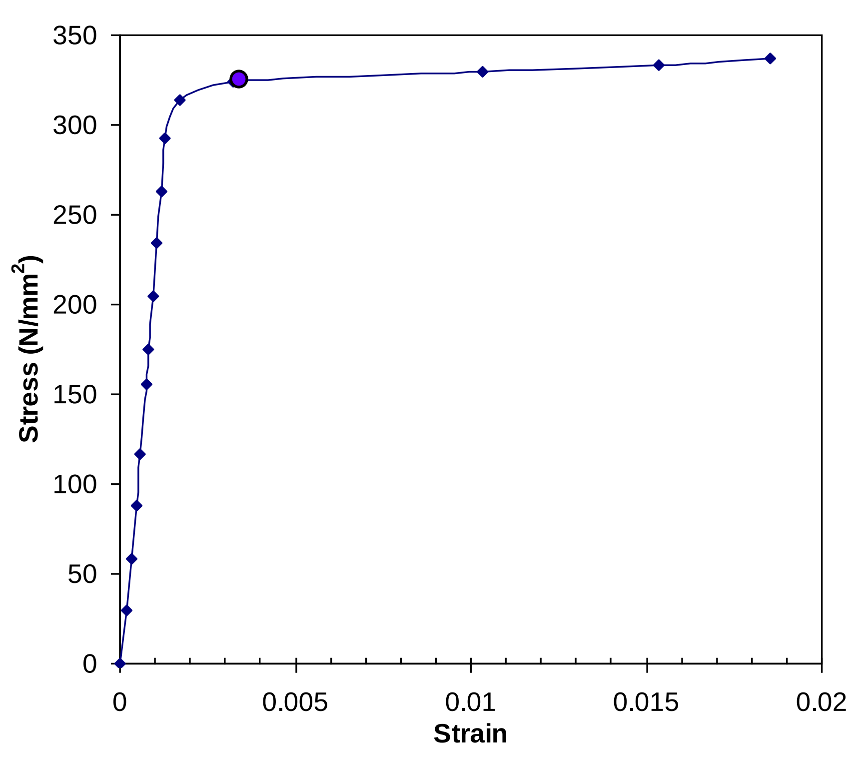
MATERIAL PROPERTIES OF STEEL REINFORCEMENT

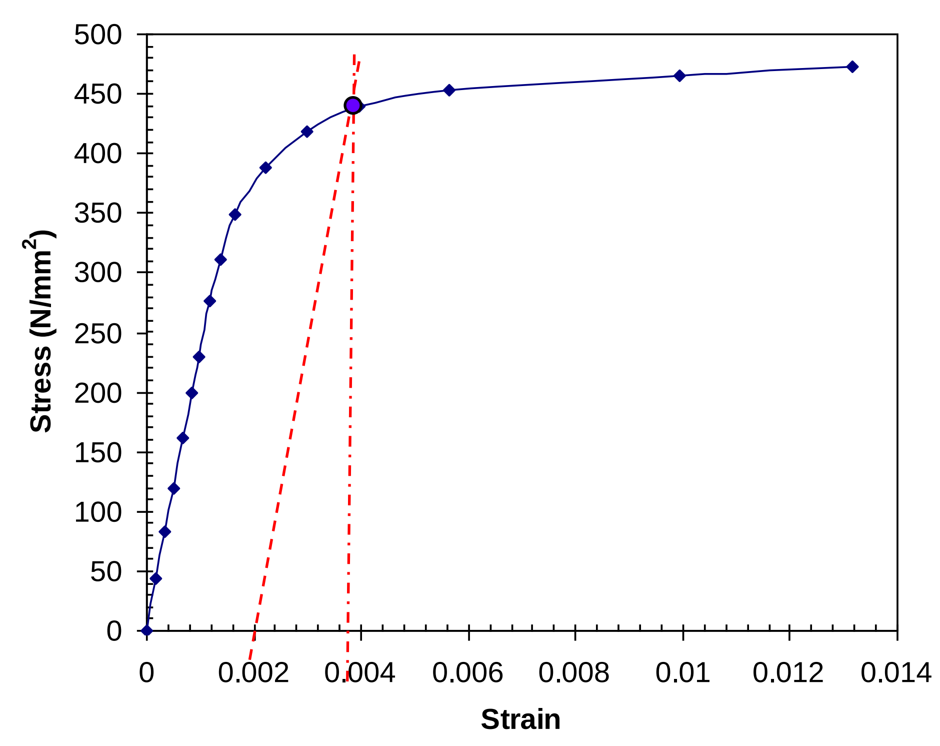


Test Setup for Steel Reinforcement Testing

MATERIAL PROPERTIES

Sl. No.	Diameter of the Rebar (mm)	Yield Strain (mm/mm)	Yield Stress (N/mm^2)	Ultimate Stress (N/mm^2)	Young's Modulus (N/mm^2)
1	6	0.0032	324	608	2.05×10^5
2	8	0.0037	435	640	2.2×10^5





Stress vs Strain curve for 6mm mild steel bar

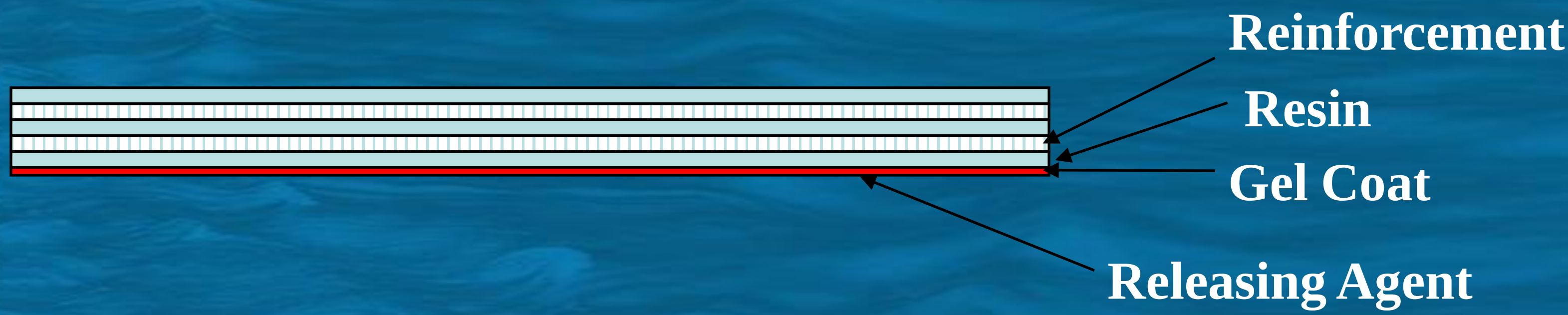
Stress vs Strain curve for 8 mm HYSD steel bar

MATERIAL PROPERTIES OF GFRP COMPOSITES

Materials Tested

Resin : Epoxy

Reinforcement : ECR Glass WRM 610gsm

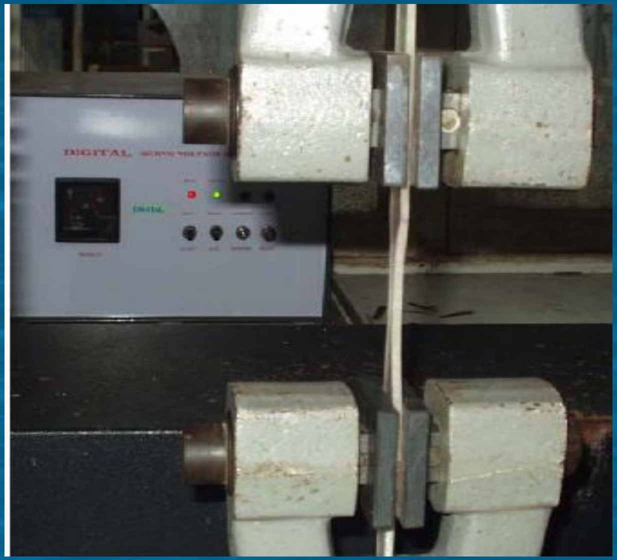


Structure Through Thickness of Laminate in Hand Lay–up Process

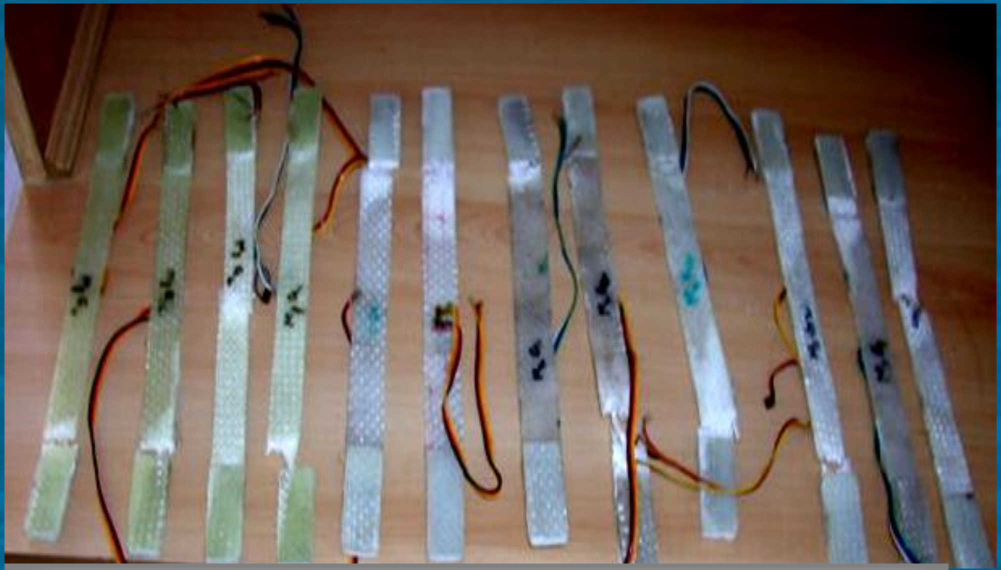
CHARACTERIZATION OF FRP COMPOSITE MATERIALS

Instron Testing Machine

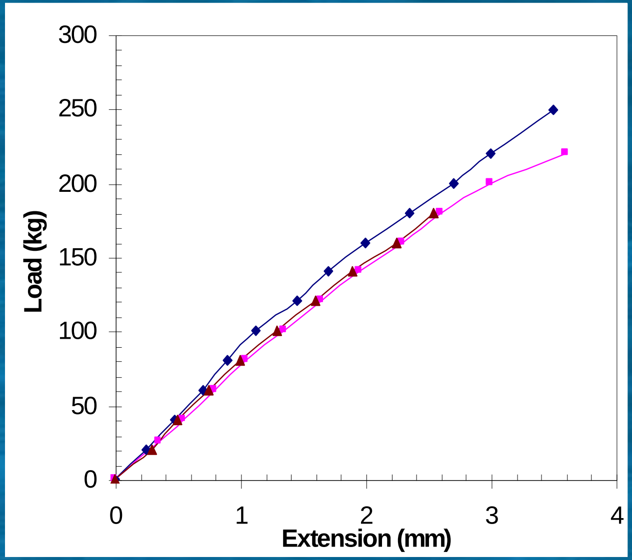
Flexure Test Set-up



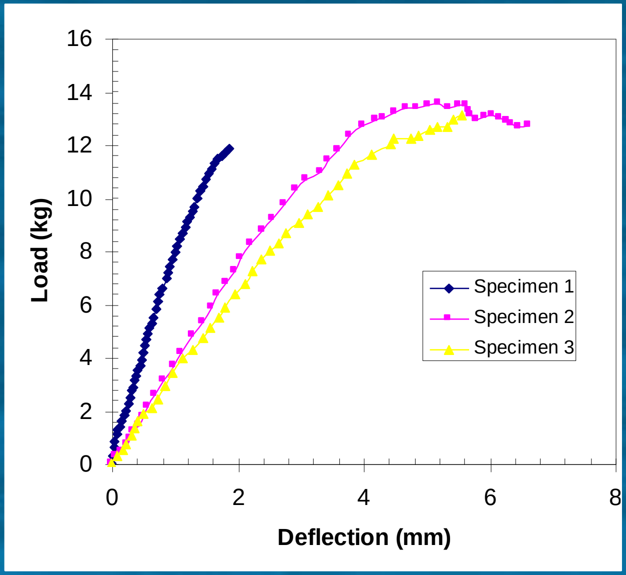
CAST RESIN TENSION TEST COUPON



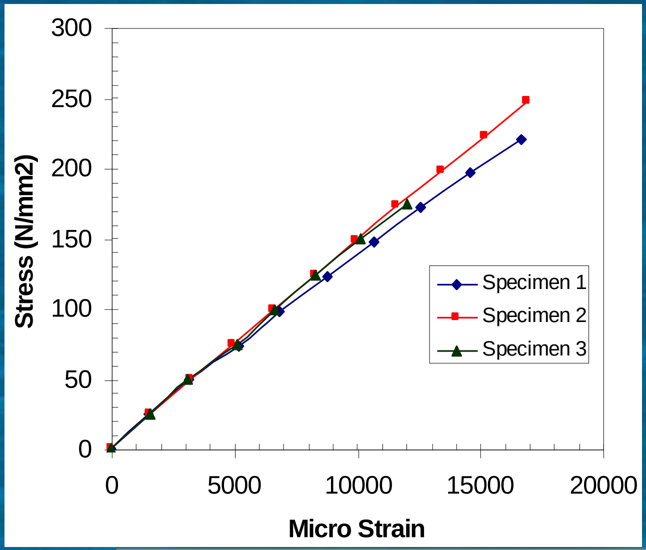
TENSION TEST COUPONS OF GFRP

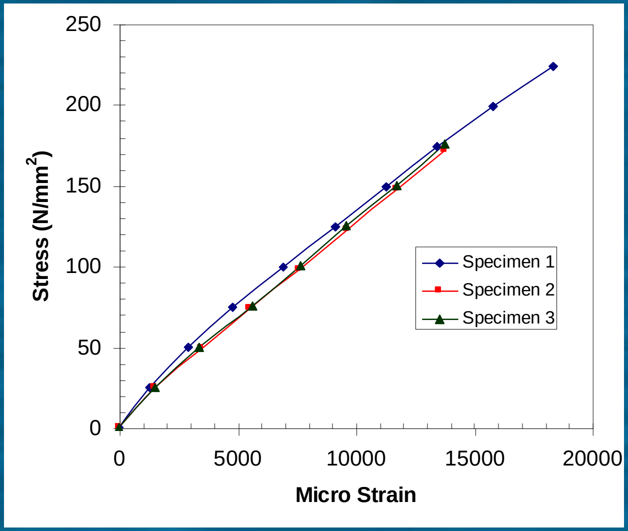


LOAD/EXTENSION CURVE FOR CAST RESIN IN TENSION

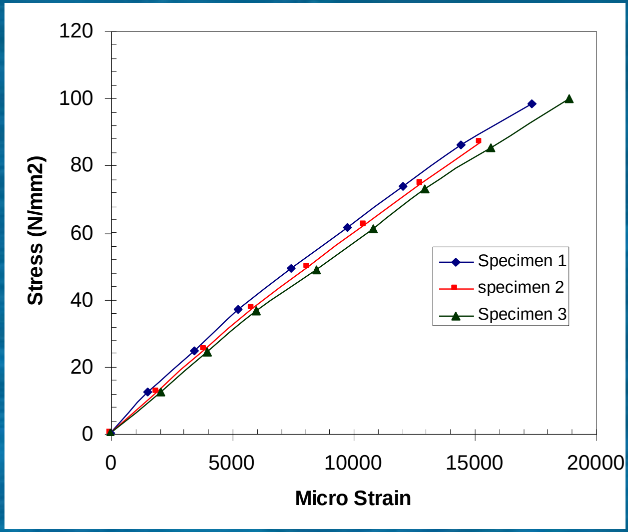


LOAD/EXTENSION CURVE FOR CAST RESIN IN FLEXURE

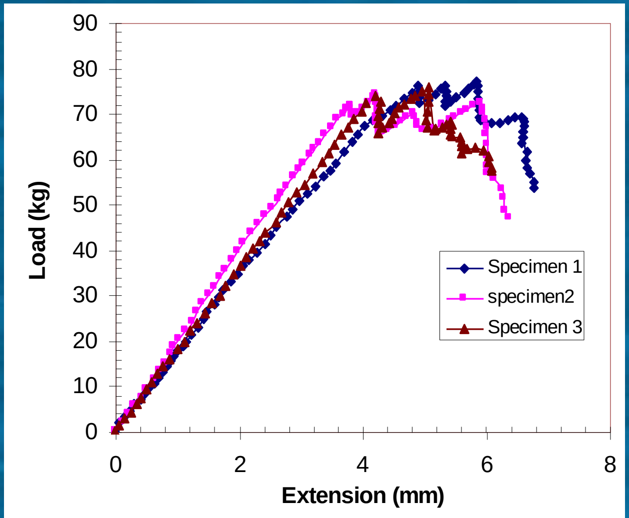




Stress/Strain Curve for GFRP Composite in Warp and Wept Direction



Stress/Strain Curve for GFRP Composite in 45^0 Direction



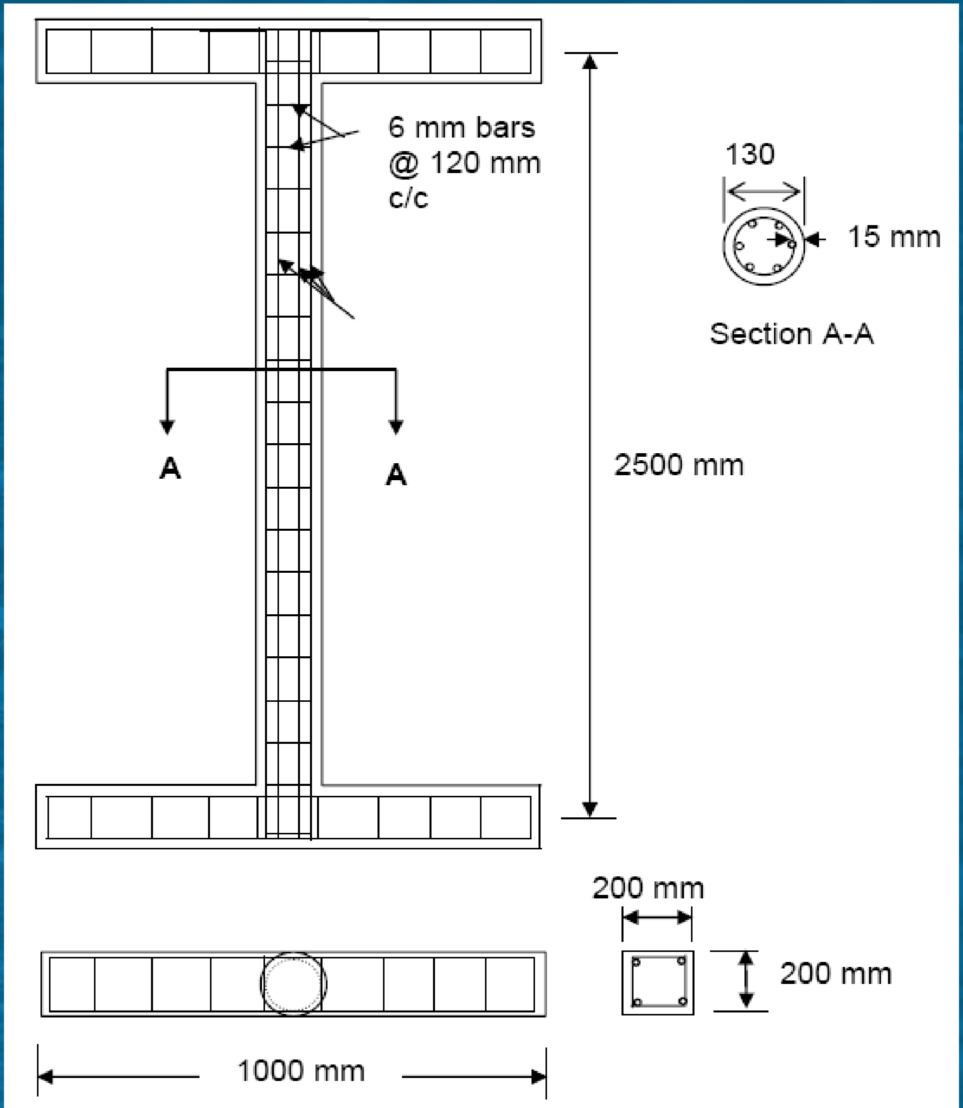
Load/Deflection Curve for GFRP Composite in in Flexure

MATERIAL PROPERTIES OF CAST RESIN

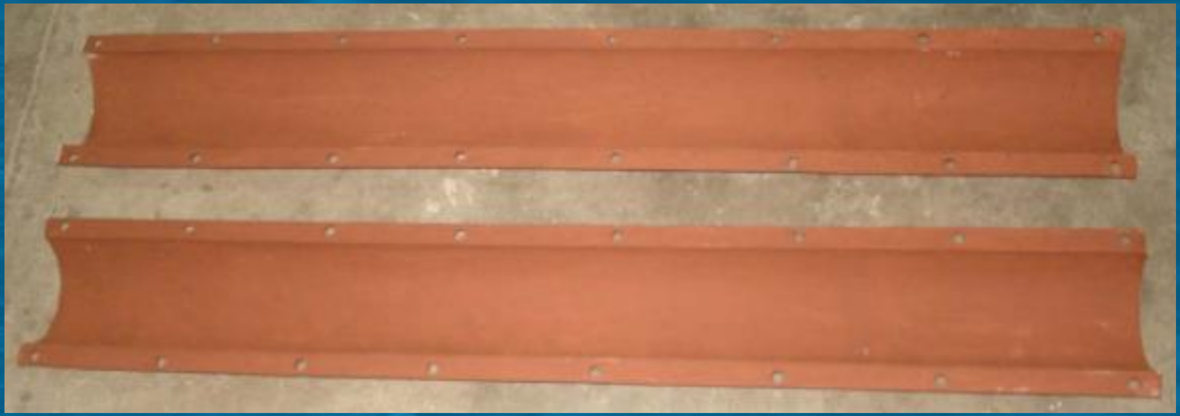
Sl. No.	Property	Standards	Value
1	Specific gravity	BIS 6746-1994	1.17
2	Viscosity	BIS 6746:1994	9433 centipoise
2	Gel time	BIS 6746-1994	55 minutes
3	Peak exothermic Temperature	BS 2782:1994: Method 111-D	69˚C
4	Heat Deflection Temperature	BS 2782: Part1: 1994:Method 121A	93˚ C
5	Hardness	ASTM: D 2583-95	23
6	Tensile Properties (i) Tensile Strength (ii) Tensile Modulus	ISO 3268- 1978 (E)	69 N/mm^2 2124 N/mm^2
7	Flexural Properties (i) Flexural Strength (ii) Flexural Modulus	ISO 178- 1975 (E)	112 N/mm^2 2888 N/mm^2
8	Izod Impact Energy	ISO 180/1A of ISO: 180-1982(E)	9.41 kJ/m^2

MATERIAL PROPERTIES OF GFRP COMPOSITE

Sl.No	Description	Standards	Results
1	Tensile Properties (i). Tensile Strength in Warp Direction (ii). Tensile Modulus in Warp direction, E_1 (iii). Poission's ratio υ_{12} (iv). Tensile Strength in Weft Direction (v). Tensile Modulus in Weft Direction, E_2 (vi). Shear Modulus G_{12}	ISO 3268- 1978 (E)	260 N/mm^2 14708 N/mm^2 0.16 248 N/mm^2 13886 N/mm^2 2632 N/mm^2
2	Flexural Properties (i). Flexural Strength (ii). Flexural Modulus	ISO 178- 1975(E)	285 N/mm^2 11477 N/mm^2
3	Shear Strength (i). Short Beam Method (ii). Lap Shear	ASTM D2344 and ASTM D3846-02	22 N/mm^2 13 N/mm^2
4	Izod Impact Energy	ISO 180 – 1982 (E)	4.60 J/cm
5	Volume Fraction of Fibers	BS 2782: Part 10: Method 1002: 1977	34 %
6	Water absorption	ISO: 62 - 1980 (E) Method -1	0.13%



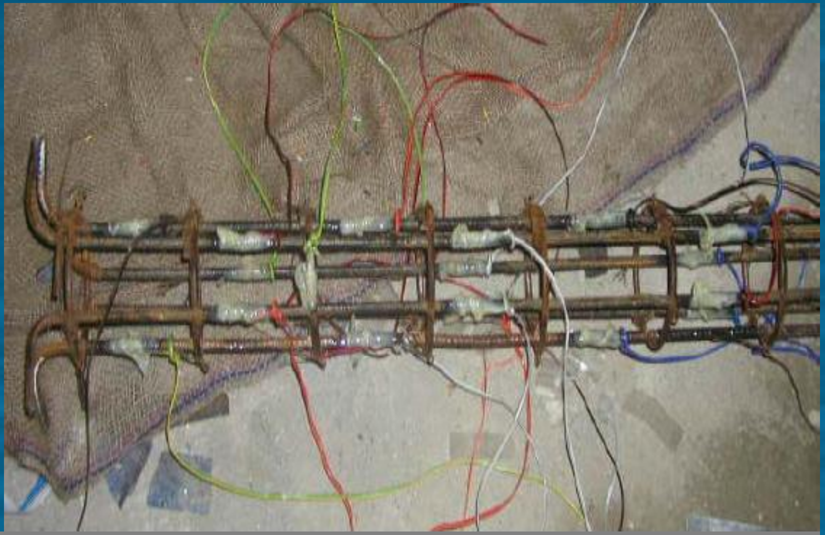
Geometry and Reinforcement Details of RC Pile



Steel Mould used for casting Column

Wooden Mould used for casting Beams

Reinforcement Cage



Water Proofing of Strain Gauges

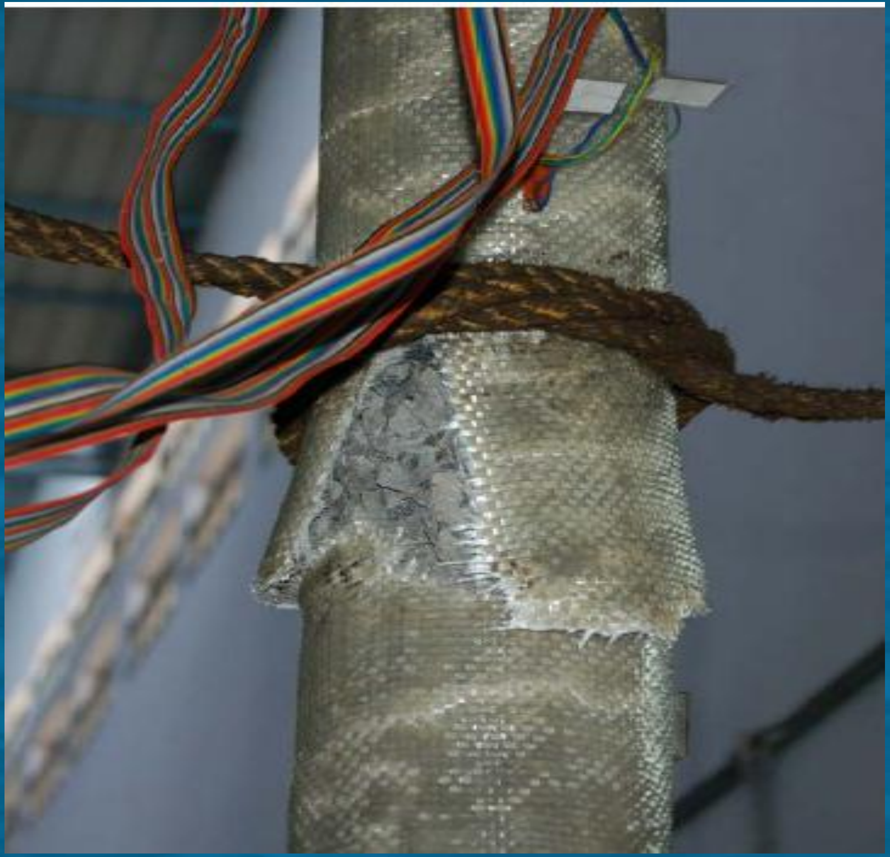
Casting of Pile Specimen

Cast Pile Specimen

Experimental Setup for Axial Compression

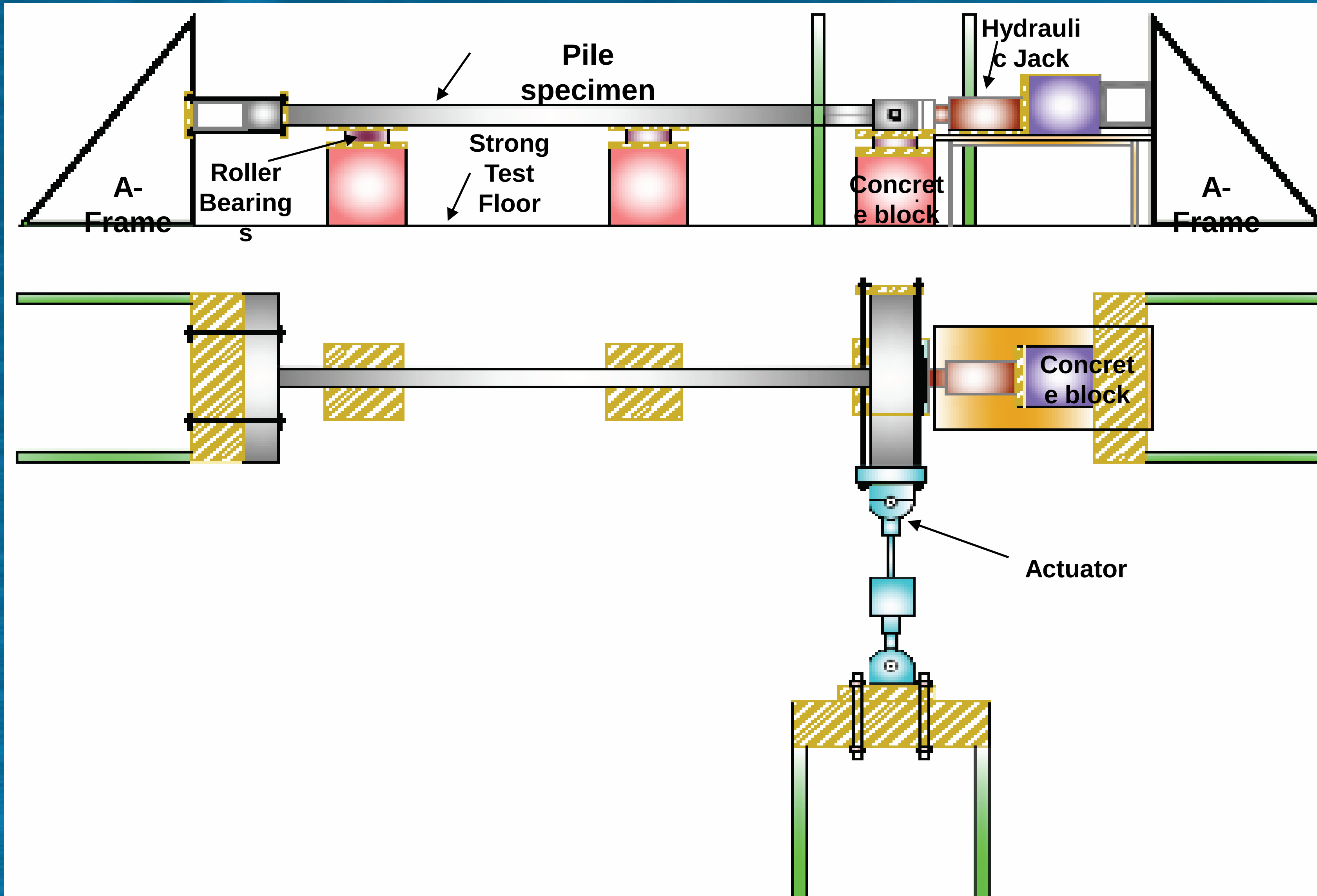
Failure Mode of Specimen CA1

Cracking of Resin Just Before Rupture of Fabric in Specimen RTA1



Failure of GFRP Wrap by Rupture in Specimen RTA1

Experimental Setup for Lateral Load


Pile
specimen
Hydrauli
c Jack
Roller
Bearing
s
Strong
Test
Floor
A-
Frame
Concret
e block
A-
Frame
Concret
e block
Actuator

Fixing the Beam with Channels

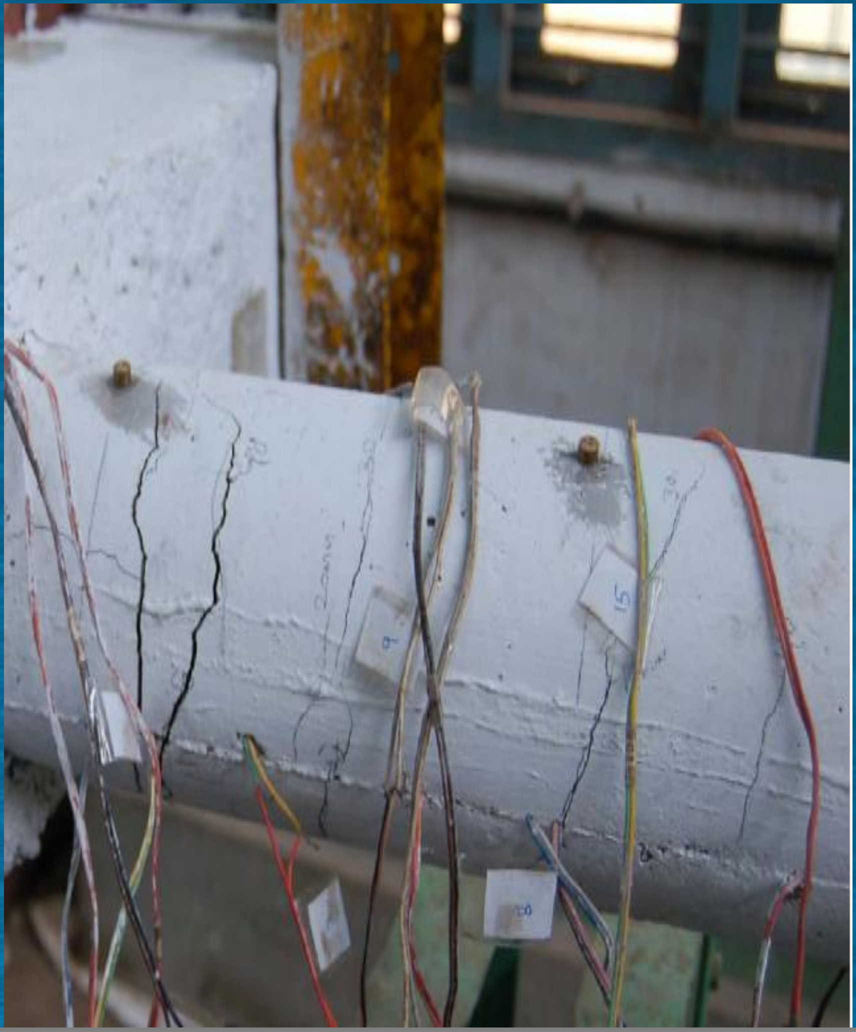
500kN Hydraulic Jack

Angular Bearing

Jack arrangement for applying axial Load

Data acquisition

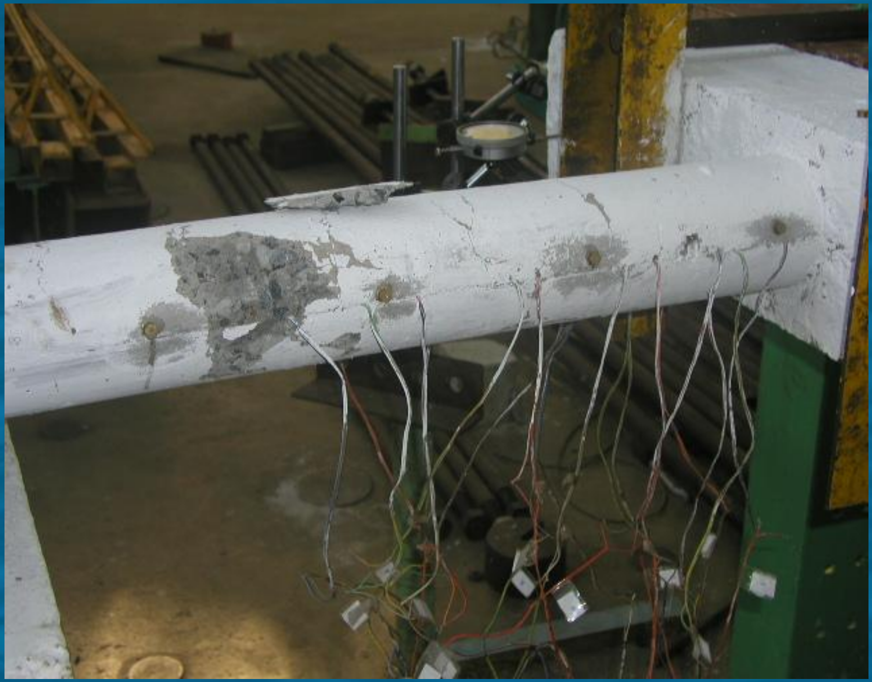
System for Applying Lateral Displacements



Failure of Pile in Tension for Specimen CL1

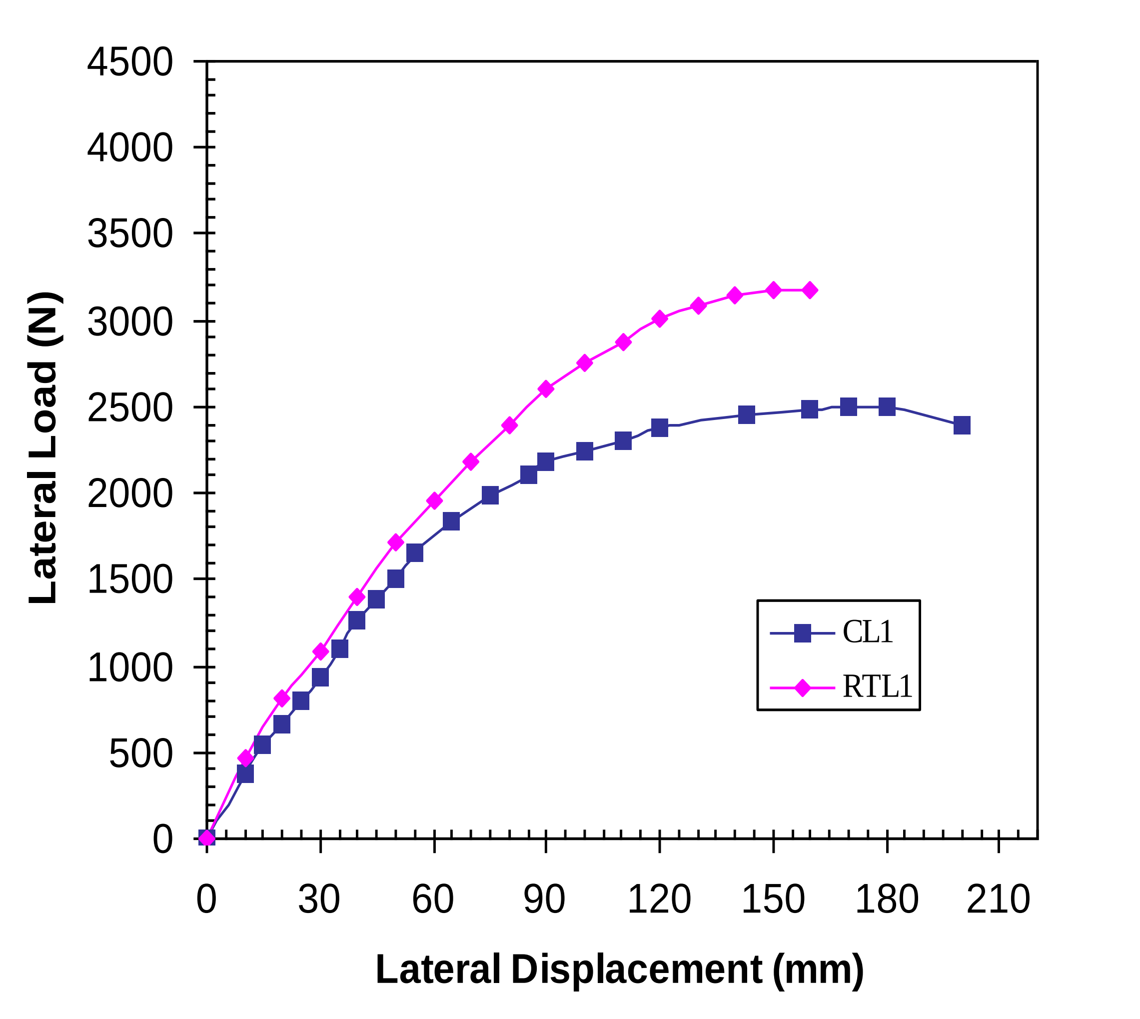
Failure of concrete in compression for Specimen CL1

Formation of Flexural Cracks on Tension Side



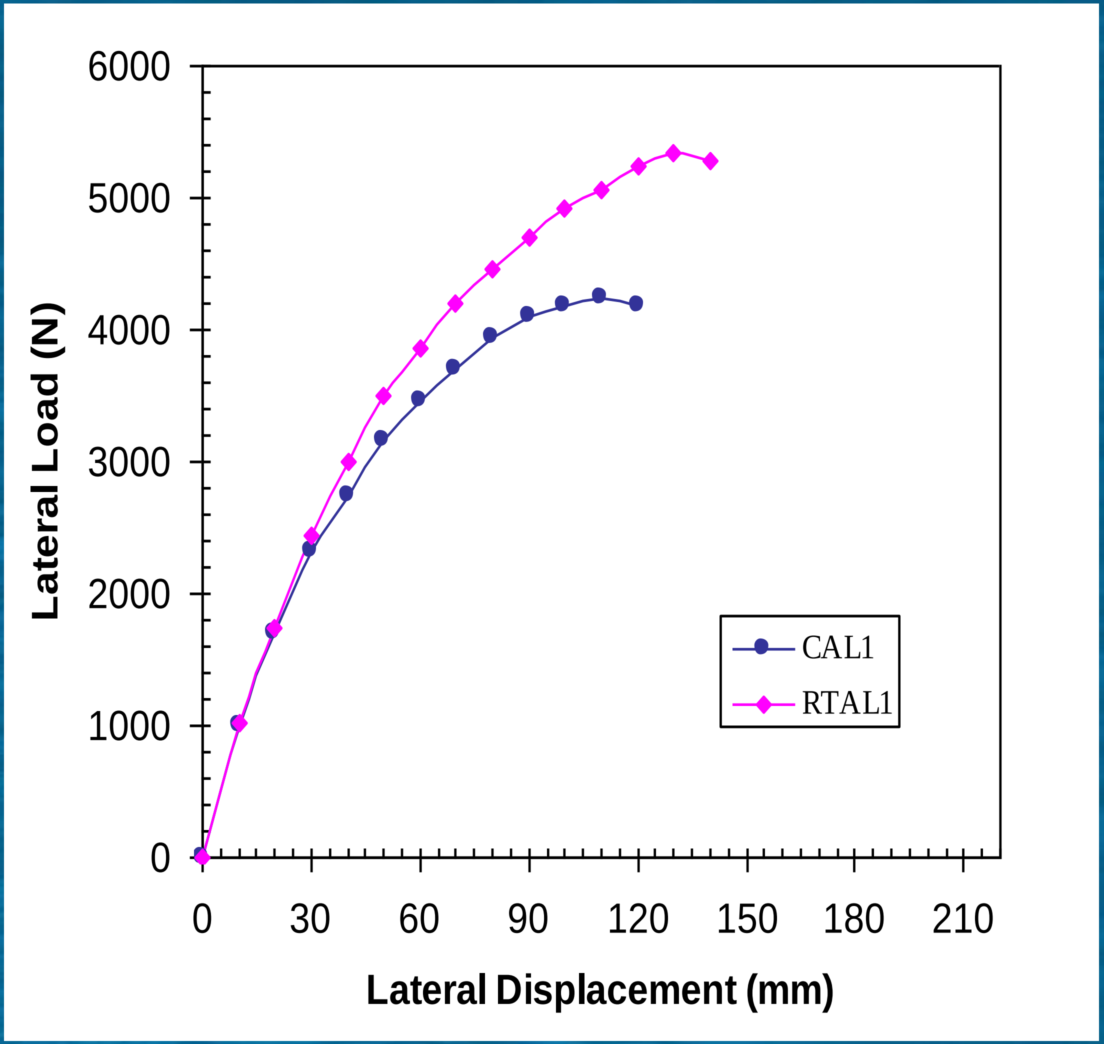
Crushing Concrete on Compression Side for Specimen CAL1

Failure or Pile Specimen RTCL1



Comparison of Lateral Load Vs Lateral Displacement

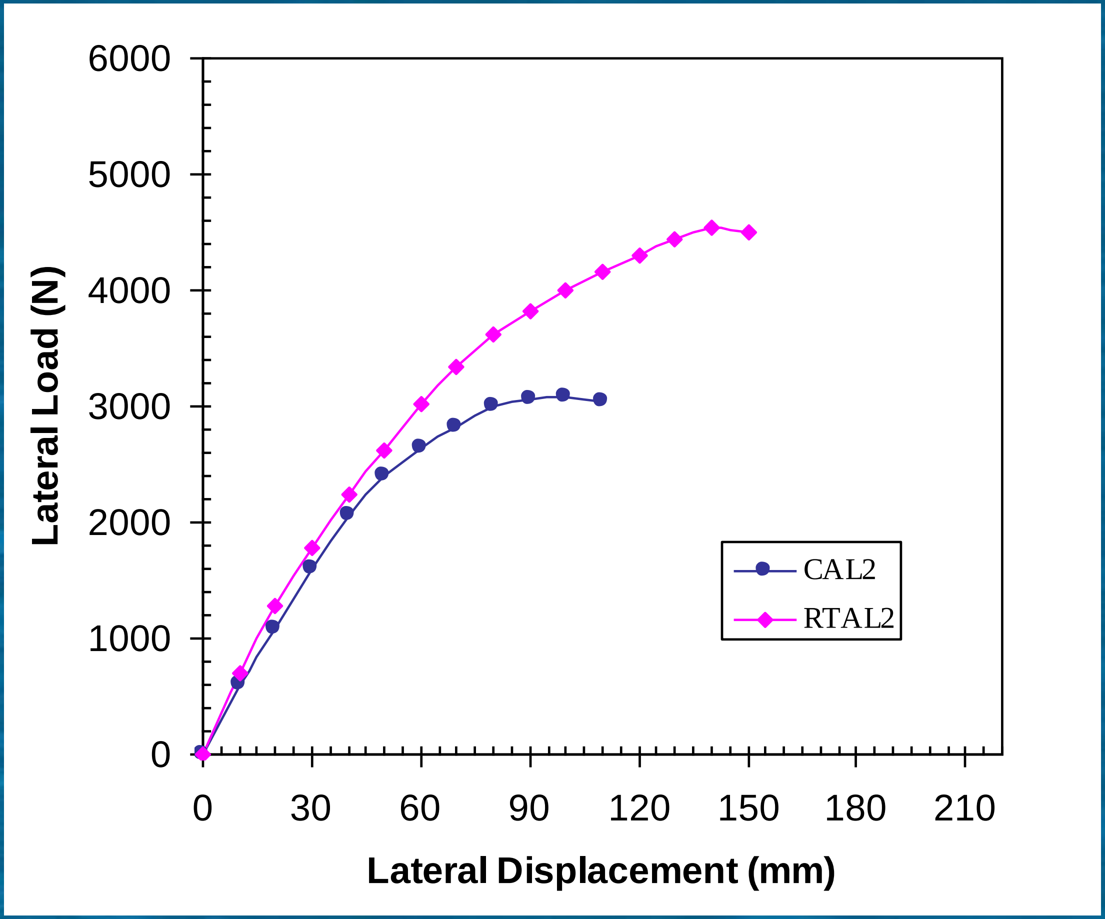
Failure of Pile Specimen RTCA1



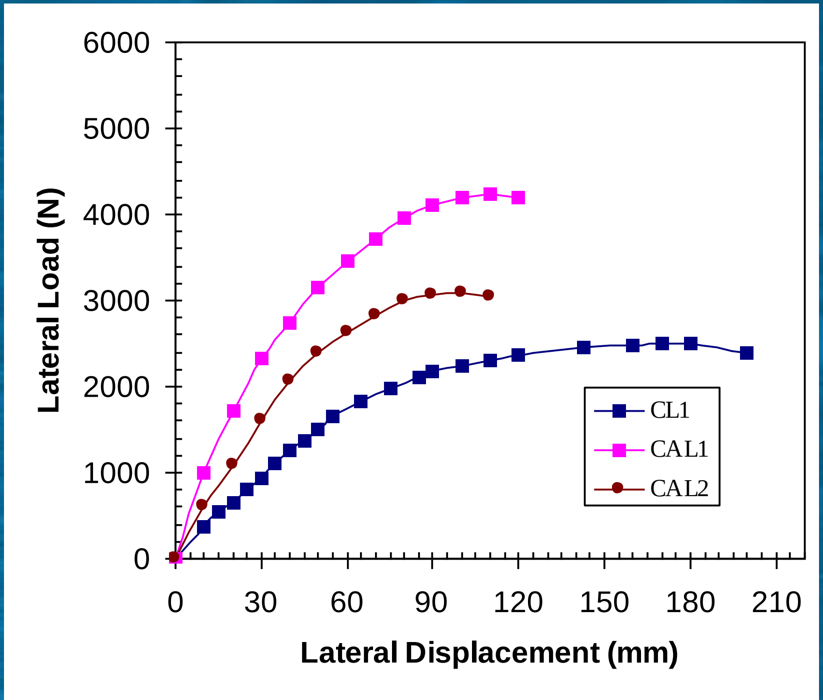
Comparison of Lateral Load Vs Lateral Displacement

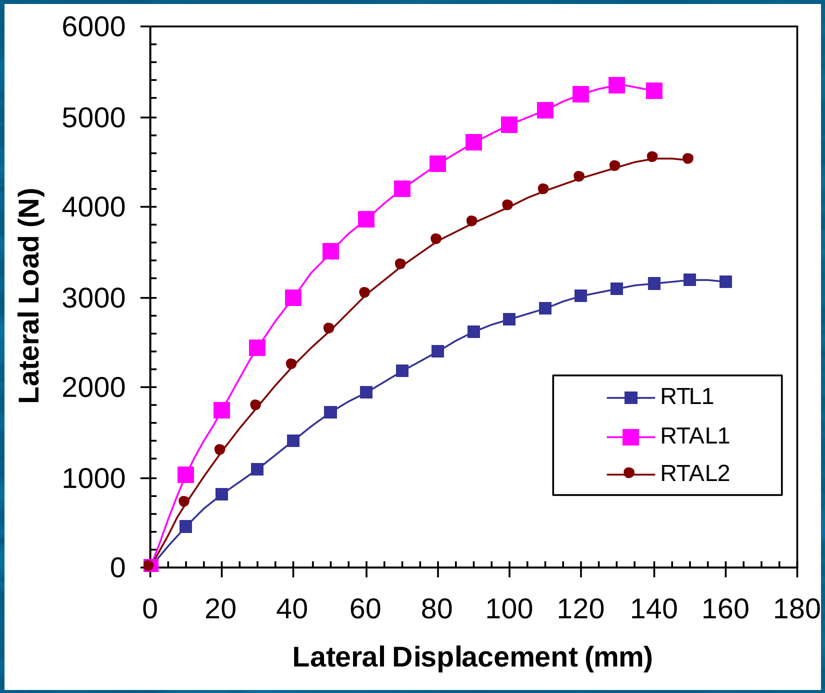
Cracking of Resin in Pile Specimen RTAL2

Cracking of RC Pile Specimen RTAL2



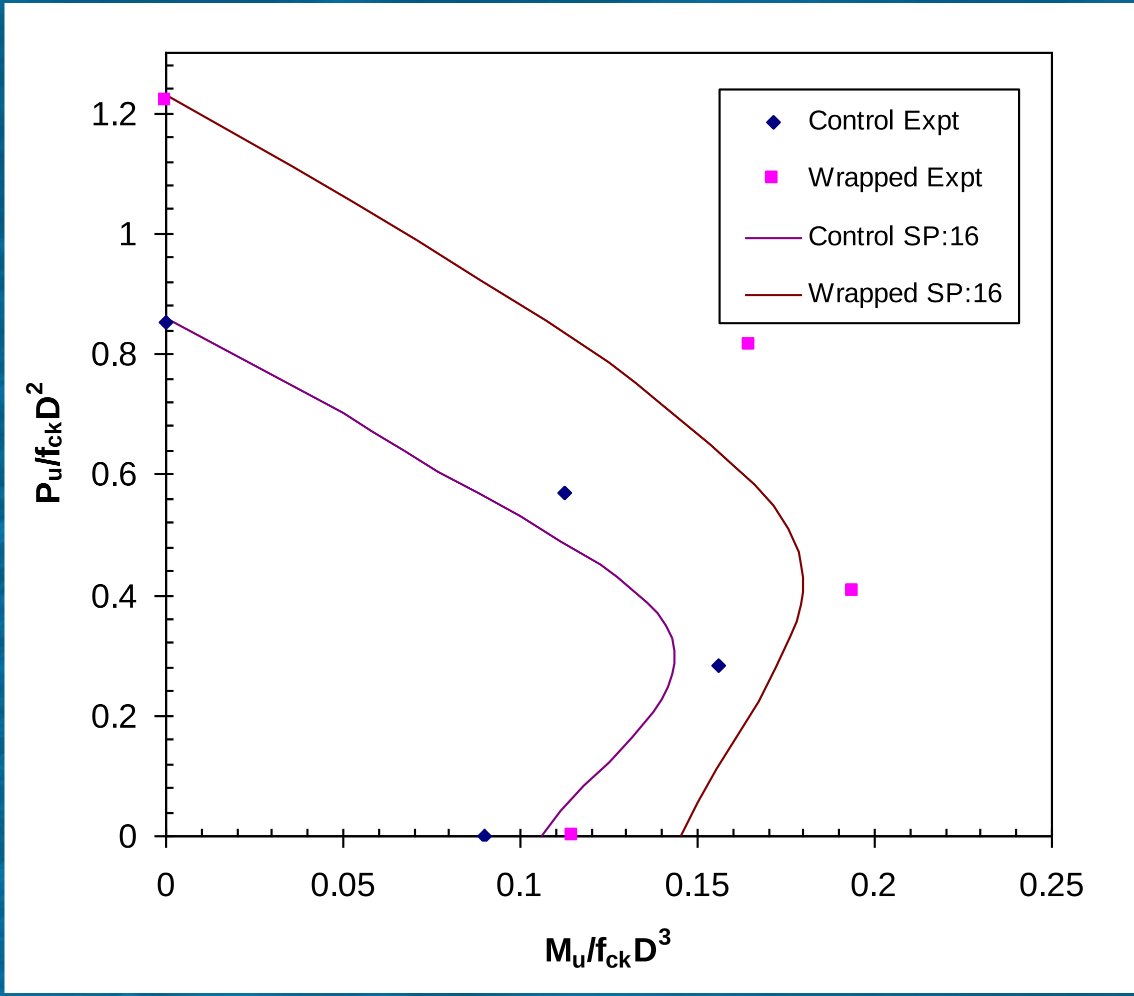
Comparison of Lateral Load Vs Lateral Displacement





Lateral Load Vs Lateral Displacement for control Specimens

Lateral Load Vs Lateral Displacement for Retrofitted Specimens

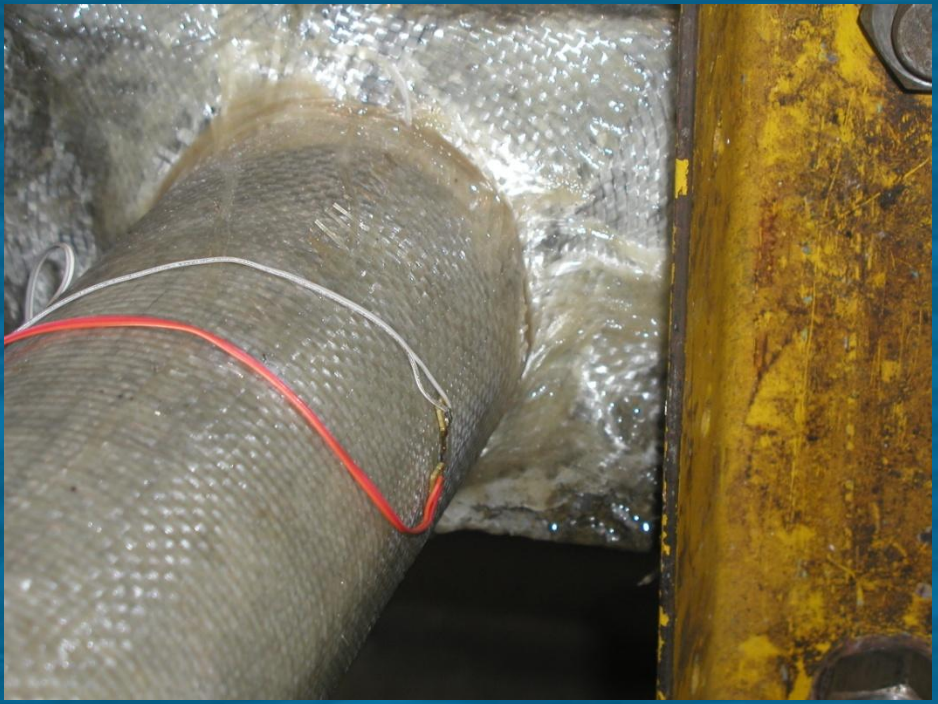


Control Expt
Wrapped Expt
Control SP:16
Wrapped SP:16
1.2
1
0.8
0.6
0.4
0.2
0
0.05
0.1
0.15
0.2
0.25
$P_u/f_{ck}D^2$
$M_u/f_{ck}D^3$

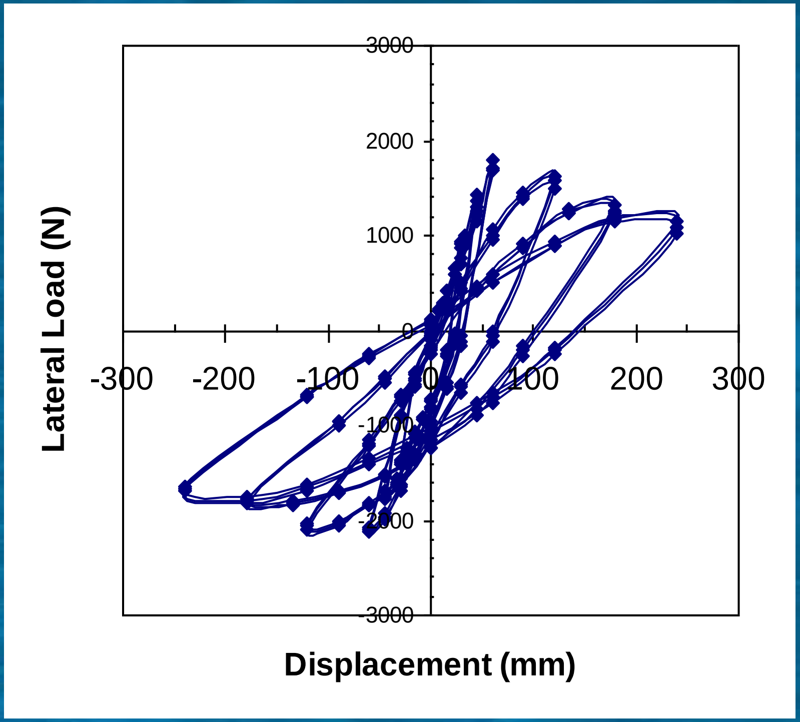
Pu-Mu Curves

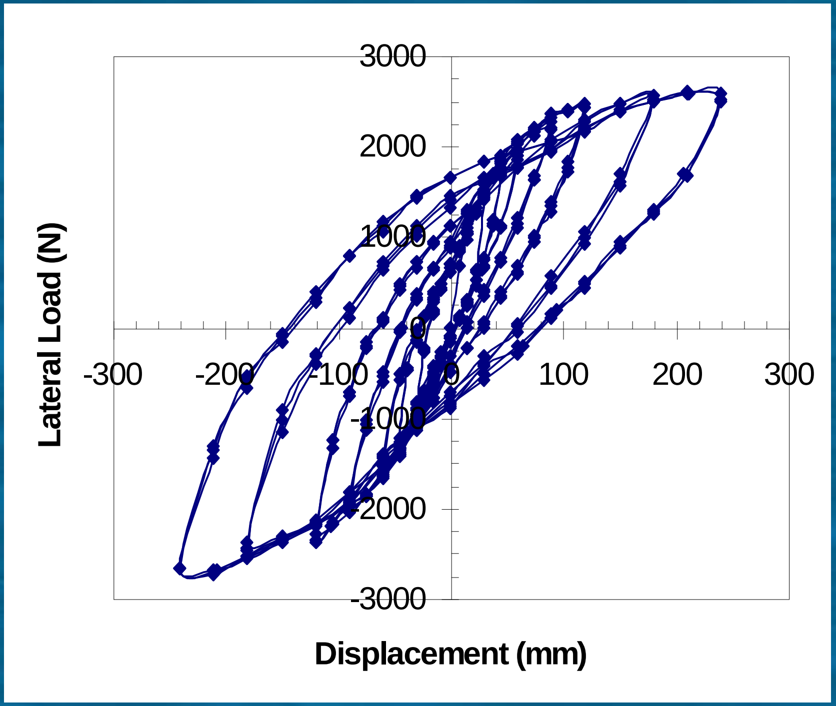
Tension cracks in Specimen CCYL1

Crushing of Concrete in Specimen CCYL1

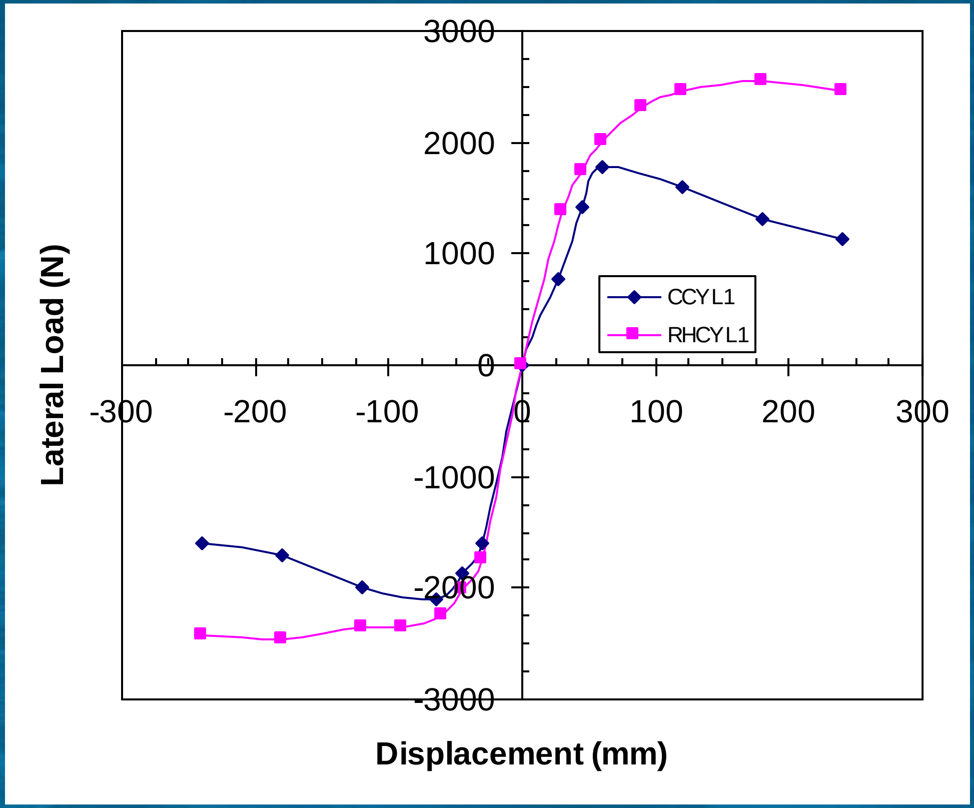


Failure of Pile Specimen RHCYL1 by Rupture of Fabric





Hysteretic loops for Control and Rehabilitated Specimens



Stiffness curves for control and rehabilitated specimens

RESULTS

- The increase in ultimate axial load carrying capacity for the retrofitted specimen over the control specimen is 58% for specimen subjected to axial compression
- The lateral load carrying capacity of the pile increases by 52%, 67% and 28% when the specimen is subjected to zero, 1/3rd and 2/3rd ultimate axial compression for static lateral load.
- The increase in lateral load capacity for the retrofitted specimen over the control specimen is 53%, 29% and 39% for specimen subjected to lateral load with zero, 1/3rd and 2/3rd ultimate axial compression.
- The control specimen subjected to cyclic lateral shows reduction in stiffness after yielding. Where as the rehabilitated specimen does not reduction and ductility performance is very good.