Strength Enhancement of Reinforced Concrete Column by Carbon Fiber 600 GSM Wrapping Retrofit Technique

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Abstract: This paper presents a comprehensive repair methodology for structural column strengthening utilizing carbon wrapping techniques with 600 GSM short description carbon fiber reinforcement polymer (CFRP). The study addresses a critical crack observed on the column top caused by laitance accumulation at basement-3, involving High flow M90 grade concrete with M-90 N/mm² compressive strength. The repair methodology begins with installation of a 20 mm MS plate from ground floor level to all five basements for temporary strengthening. Subsequently, the column top was dismantled into four parts of dimensions 400X800X800MM, matching the original column size of 1600 X 800MM. The top was re-casted in the same parts using 6 MM down aggregate mix with MCKRETE 90DS and GROUNTING by MC DUR 1264-KFTR, followed by grouting process. After concrete re-casting with Emcekrete 90DS (M-90 N/mm² compressive strength), the carbon wrapping procedure commenced with 600 GSM unidirectional carbon fiber material (SikaWrap 601C), leaving appropriate space for material application. Core strength test results confirmed 92 N/mm² average compressive strength, exceeding the M-90 requirement. The final protective system includes 15 mm thick Sikacrete 213F plaster with quartz sand key layer for fire and damage protection.

Keywords: Carbon Fiber Reinforced Polymer (CFRP), Carbon Wrapping, Structural Column Strengthening, Structural Rehabilitation, M90 Grade Concrete, Concrete Crack Repair, Epoxy Grouting, Compressive Strength, SikaWrap 601C, High-Strength Concrete.

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I. Introduction

Structural integrity in high-rise basements is paramount, particularly when utilizing high flow concrete grades. The accumulation of laitance at basement interfaces can lead to significant cracking patterns that compromise load-bearing capacity. This research focuses on a specific failure case where crack propagation occurred at the column top due to laitance accumulation at basement-3, involving High flow M90 grade concrete. The repair methodology combines mechanical reinforcement with advanced carbon fiber wrapping techniques to restore structural capacity.

II. Problem Statement

The primary issue identified was a crack on the column top resulting from laitance accumulation at PROJECT-XYZ. The concrete used was High flow M90 grade (M-90 N/mm² compressive strength), which, despite its high flow properties, experienced surface defects at the basement interface. This defect necessitated an advanced repair methodology combining mechanical plate installation, concrete re-casting, and carbon fiber wrapping techniques. The column dimensions measured sixteen hundred by eight hundred millimeters, with the damaged area requiring removal of eight hundred by two hundred by six hundred millimeters.

III. Objectives of the Study

The main objectives are:

- Temporary Strengthening: Install structural support system from basement 5 to ground floor level using propping and MS plates.
- Concrete Removal: Remove damaged concrete section using lightweight chipper machinery (TE-500 Hilti).
- Re-casting: Replace with Emcekrete 90DS non-shrink grout material with M-90 compressive strength in eight sequential parts.
- Anchoring: Install M24 anchor rods with HIT-RE 500 V4 adhesive system and 135mm embedment depth.
- Carbon Wrapping: Apply 600 GSM CFRP system (SikaWrap 601C) for final strengthening with proper priming and saturant.
- Quality Verification: Conduct core strength tests, anchor pull-out tests, and weld joint tests for validation.

IV. Tests Conducted

Non-Destructive Test

The ultrasonic pulse velocity (UPV) test by the direct method is a non-destructive testing technique used to evaluate the quality, homogeneity, and compressive strength of concrete by measuring the transit time of an ultrasonic pulse through the material. In this method, the transmitter and receiver transducers are positioned on opposite faces of the concrete specimen or structural element, ensuring the pulse travels at right angles to the transmitter face, which provides the most accurate and reliable measurement of transit time compared to semi-direct or indirect transmission arrangements. The pulse velocity is calculated using the fundamental relationship $V = L/T$, where V represents the pulse velocity, L is the path length (shortest distance between transducers), and T is the measured transit time, with the direct method being classified as the most preferred and standardized arrangement in international testing protocols due to its superior reliability and minimal energy loss during transmission.

Table 1 UPV Test Results before repair (Face I)

RESULT OF ULTRASONIC PULSE VELOCITY TEST										
MEMBERS TESTED				: RC COLUMN						
PERIOD OF TEST				: 14.08.2023						
TEST INSTRUMENT				: PUNDIT LAB+ (Portable Ultrasonic Non-Destructive Digital Indicating Tester)						
MAKE				: M/S PROCEQ, SWITZERLAND						
TECHNICAL REFERENCE				: Indian Standard Code:- IS:516(PART 5/SEC 1):2018 (Amendment-November 2019)						
SITE NAME: PROJECT XYZ										
Sr. No.	Grade of Concrete	Member Identification	Grid/ Location Identification	Path Length (m)	Time (micro seconds)	Actual Velocity (m/sec)	Method of Test	Correction Factor	Final Velocity (km/sec)	Concrete Quality Grading
BASEMENT 3, RC COLUNMN, S/18, (800x1600 mm) FACE-I										
1	M90	RC COLUMN	B3 - S/18 - 01	0.800	346.0	2312	DIRECT	NA	2.31	Doubtful
2	M90	RC COLUMN	B3 - S/18 - 02	0.800	358.0	2235	DIRECT	NA	2.23	Doubtful
3	M90	RC COLUMN	B3 - S/18 - 03	0.800	366.0	2186	DIRECT	NA	2.19	Doubtful
4	M90	RC COLUMN	B3 - S/18 - 04	0.800	288.0	2778	DIRECT	NA	2.78	Doubtful
5	M90	RC COLUMN	B3 - S/18 - 06	0.800	346.0	2312	DIRECT	NA	2.31	Doubtful

Table 2 UPV Test Results before repair (Face I & Face II)

RESULT OF ULTRASONIC PULSE VELOCITY TEST										
MEMBERS TESTED				: RC COLUMN						
PERIOD OF TEST				: 14.08.2023						
TEST INSTRUMENT				: PUNDIT LAB+ (Portable Ultrasonic Non-Destructive Digital Indicating Tester)						
MAKE				: M/S PROCEQ, SWITZERLAND						
TECHNICAL REFERENCE				: Indian Standard Code:- IS:516(PART 5/SEC 1):2018 (Amendment-November 2019)						
SITE NAME: PROJECT XYZ										
Sr. No.	Grade of Concrete	Member Identification	Grid/ Location Identification	Path Length (m)	Time (micro seconds)	Actual Velocity (m/sec)	Method of Test	Correction Factor	Final Velocity (km/sec)	Concrete Quality Grading
BASEMENT 3, RC COLUNMN, S/18, (800x1600 mm) FACE-I										
1	M90	RC COLUMN	B3 - S/18 - 05	0.800	209.0	3828	DIRECT	NA	3.83	Good
2	M90	RC COLUMN	B3 - S/18 - 07	0.800	186.9	4280	DIRECT	NA	4.28	Good
3	M90	RC COLUMN	B3 - S/18 - 09	0.800	183.4	4362	DIRECT	NA	4.36	Good
4	M90	RC COLUMN	B3 - S/18 - 10	0.800	177.9	4497	DIRECT	NA	4.50	Good
5	M90	RC COLUMN	B3 - S/18 - 14	0.800	187.4	4269	DIRECT	NA	4.27	Good
BASEMENT 3, RC COLUNMN, S/18, (800x1600 mm) FACE-II										
6	M90	RC COLUMN	B3 - S/18 - 05	1.600	383.0	4178	DIRECT	NA	4.18	Good
7	M90	RC COLUMN	B3 - S/18 - 06	1.600	368.0	4348	DIRECT	NA	4.35	Good
8	M90	RC COLUMN	B3 - S/18 - 08	1.600	366.0	4372	DIRECT	NA	4.37	Good
9	M90	RC COLUMN	B3 - S/18 - 09	1.600	357.0	4482	DIRECT	NA	4.48	Good
10	M90	RC COLUMN	B3 - S/18 - 10	1.600	366.0	4372	DIRECT	NA	4.37	Good
11	M90	RC COLUMN	B3 - S/18 - 11	1.600	374.0	4278	DIRECT	NA	4.28	Good
12	M90	RC COLUMN	B3 - S/18 - 12	1.600	394.0	4061	DIRECT	NA	4.06	Good

Table 3 UPV Test Results before repair (Face I & II)

RESULT OF ULTRASONIC PULSE VELOCITY TEST										
MEMBERS TESTED				: RC COLUMN						
PERIOD OF TEST				: 14.08.2023						
TEST INSTRUMENT				: PUNDIT LAB+ (Portable Ultrasonic Non-Destructive Digital Indicating Tester)						
MAKE				: M/S PROCEQ, SWITZERLAND						
TECHNICAL REFERENCE				: Indian Standard Code:- IS:516(PART 5/SEC 1):2018 (Amendment-November 2019)						
SITE NAME: PROJECT XYZ										
Sr. No.	Grade of Concrete	Member Identification	Grid/ Location Identification	Path Length (m)	Time (micro seconds)	Actual Velocity (m/sec)	Method of Test	Correction Factor	Final Velocity (km/sec)	Concrete Quality Grading
BASEMENT 3, RC COLUNMN, S/18, (800x1600 mm) FACE-I										
1	M90	RC COLUMN	B3 - S/18 - 08	0.800	177.4	4510	DIRECT	NA	4.51	Excellent
2	M90	RC COLUMN	B3 - S/18 - 11	0.800	172.4	4640	DIRECT	NA	4.64	Excellent
3	M90	RC COLUMN	B3 - S/18 - 12	0.800	171.4	4667	DIRECT	NA	4.67	Excellent
4	M90	RC COLUMN	B3 - S/18 - 13	0.800	176.9	4522	DIRECT	NA	4.52	Excellent
BASEMENT 3, RC COLUNMN, S/18, (800x1600 mm) FACE-II										
5	M90	RC COLUMN	B3 - S/18 - 07	1.600	353.0	4533	DIRECT	NA	4.53	Excellent

Figure 1: Location of UPV Test Conducted

Core Cutter Test

The objectives of the core cutter test include visual inspection of the concrete interior, determining compressive strength through laboratory testing, and conducting chemical testing for density, water absorption, indirect tensile strength, and expansion due to alkali aggregate reaction. Typically, at least 3 cores are taken from each location in the structure for strength determination, with core diameter preferably at least three times the nominal maximum size of coarse aggregate and length nearly twice its diameter for accurate results. Results are interpreted such that if core strength is below 75% of the design strength, additional testing or structural strengthening may be required.

Table 4: Concrete Core Test Results

TEST REPORT ON CONCRETE CORE

Source of Sample* : PROJECT XYZ
No. of Sample Tested : 1 (One)
Customer Reference* : Email Dated 15.11.2023
Project* : PROJECT XYZ
Condition of Sample : Satisfactory
Sample Drawn By : Core drawn by Mr. X Representative
Sample Identification* : Concrete Core, Core -3, Basement 3,
Grade/Type* : M-90
Brand* : Not Furnished
Period of Test : 15.11.2023 to 20.11.2023

Mechanical Testing-(Building Materials)-Concrete Core

S. No	Weight Kg	Length, mm	Diameter ,mm	Crushing Load, Kn	Comp. Strength ,N/mm^2	Corrected Compressive Strength, N/mm^2 CCS*H/D*1.06	Equivalent Cube Strength, N/mm^2 (CCS *1.25)	Test Method
1.	1.006	117.20	68.13	29242	80.18	82.38	103.0	IS:516-(Part-IV)-2018

Compressive Strength

M90 grade concrete is classified as high-strength concrete (HSC), where the number 90 denotes the characteristic compressive strength of 90 MPa (or 90 N/mm²) measured on standard 150 mm concrete cubes after 28 days of curing. According to Indian Standards, the characteristic strength (fck) is defined as the strength below which not more than 5% of test results are expected to fall. High-strength concrete such as M90 is produced using a low water–cement ratio, mineral admixtures like silica fume, and superplasticizers to achieve superior strength and durability. Due to its excellent mechanical properties, M90 concrete is widely used in high-rise buildings, bridges, and other heavily loaded structures requiring enhanced performance and long service life.

Table 5 Compressive Strength after re-cast part of Column(M90)

CONCRETE CUBE SAMPLE TEST RESULT							
Level	Col: Name	Strength Days	1st Part	2nd Part	3rd Part	4th Part	Avg. Strength
B3	S|18	7 Days	76.64	76.77	80.23	75.95	77.40
		14 Days	79.18	87.15	87.38	86.61	85.08
		28 Days	95.36	96.93	95.64	97.39	96.33

V. Work Method and Sequence of Execution

Propping and Temporary Strengthening

Propping shall be done between grids R-T and 17-19 on all sides from B5 level up to ground floor level. Two-sided 40mm thickness MS steel plate (E450MPa) with anchor M24 will be installed with the column as properly structured support per consultant recommendation SSK-89. This temporary strengthening system provides essential load distribution during concrete removal and re-casting operations.

Reinforcement Layout and Scanning

Lay-out of reinforcement as per drawing will be done on the objective column according to drawing number SSK-89. Reinforcement scanning is conducted through bar locator to identify reinforcement positions accurately. Holes of 135mm embedment depth are made at the scanned places with the drill machine. Before fixing anchors, clean the hole thoroughly with a blower machine. This systematic approach ensures proper anchor placement without interfering with existing reinforcement.

MS Steel Plate Preparation

Prepare MS steel plate 800mm×3400mm length and 40mm thickness from JSPL 450 grade steel. Through the template, first take the impression of the hole in the template, then transfer the same impression to the MS steel plate. Holes are drilled in the MS plate by the hole drill cutter machine. This precision preparation ensures accurate hole alignment for anchor rod installation.

Anchor Rod Installation

Fixing the anchor rod HIT-RE 500 V4 + HAS-U 8.8 M24 with 135mm embedment depth using HIT-Re 500V4 adhesive in the place of hole in the objective RCC column. The Hilti anchor rod HAS pull-out test will be performed by Hilti India Pvt. Ltd. to verify anchoring system performance. Fixing both side MS plates of column (800mm side) as per installation requirements. This anchoring system provides the mechanical connection between MS plates and concrete substrate.

Stiffener Installation and Welding

After fixing the MS plate, stiffeners at the top and bottom will be fixed as per detail provided by consultant. The stiffener weld joint test is performed as per welding procedures AWS D1.1. This welding standard ensures complete fusion and structural integrity of the stiffener connections. The stiffener system provides additional load distribution and prevents plate deformation.

VI. Dismantling and Concrete RE Casting Process

Concrete Removal Sequence Concrete removal shall be done only after all structural steel work is complete along with back propping from B5 to ground floor slab. Concrete removal is performed by lightweight chipper machine (TE-500 by Hilti). This sequence ensures the temporary strengthening system is fully operational before removing damaged concrete, preventing structural instability during the removal process.

Figure 2: Column top Dismantled partwise

Re-casting with Emcekrete 90DS After temporary strengthening, concrete shall be removed in 800×200×600mm area and replaced/filled with Emcekrete 90DS, non-shrink grout material with compressive strength M-90 N/mm² after 28 days in sequence as per drawing SSK-89. After removal of concrete, fix one side shutter and pour Emcekrete 90DS from the second side. This first part casting establishes the initial structural restoration.

Figure 3: Emcekrete 90DS mixing with 6mm Down concrete design mix

Sequential Part Casting Process

The second part will be removed after attaining M-90 N/mm² strength. Curing shall be done as per the manufacturer's recommendation. After casting four parts of the concrete, grouting is done in case of any void left. This sequential approach allows each section to achieve full strength before proceeding to the next part, ensuring proper structural continuity.

Table 6: Sequential Part Casting Process

Part Number	Area (mm)	Strength Requirement	Sequence
Part 1	800×200×600	M-90 N/mm²	First
Part 2	800×200×600	M-90 N/mm²	After Part 1 strength
Part 3	800×200×600	M-90 N/mm²	After Part 2 strength
Part 4	800×200×600	M-90 N/mm²	After Part 3 strength
Grouting	All voids	Complete filling	After Part 8

Figure 4: Concrete Cube Sampling done as per IS 456:2000

Column Grid Specific Activities

This process will be from basement 5 to ground floor level in column grid S-18, and there will be the same activity. There will be extra activity in the column of basement 3 level, which addresses the crack observed due to laitance accumulation. The basement 3 level column requires the complete eight-part casting sequence with Emcekrete 90DS, followed by CFRP wrapping with 600 GSM carbon fiber.

Curing Requirements

Curing shall be done as per the manufacturer's recommendation. Proper curing ensures the grout material achieves full compressive strength and develops optimal bond with existing concrete. The curing process maintains moisture content during the critical 28-day period, allowing complete hydration and strength development.

VII. CFRP Method Statement and Scope

Scope of CFRP Strengthening System

The following method statement is applicable for strengthening of Reinforced Cement Concrete (RCC) structural elements by wrapping the same with High Tensile, Unidirectional, Carbon Fibre Reinforcement Polymer (CFRP) System. The orientation of the fibers and laminates, and the number of layers to be applied depends upon the design specifications. The number of layers and spacing shall be based on the design approved by the Engineer in Charge. Any structural damage or distresses due to corrosion or any other reason must be repaired prior to application of the strengthening system.

Sequence of CFRP Activities

The CFRP strengthening process follows a systematic sequence comprising four primary activities:

- Surface Preparation: Removal of finishes and cleaning of concrete substrate
- Priming: Application of epoxy-based primer resin (Sikadur®-330)
- Saturant Coat & Fabric Layup: Wet application of carbon fiber sheets (SikaWrap 600GSM)
- Protective System: Installation of protective plaster layer (Sikacrete 213F)

This sequential approach ensures optimal bonding and long-term structural performance of the strengthened elements.

Surface Preparation for Carbon Fibre Wrapping

The Columns finishes/plaster shall be removed to reach mother concrete surface. The Concrete surface shall be grinded with the help of a hand grinder to remove laitance and surface contamination. The concrete must be thoroughly cleaned, free of oils, curing compounds or mould release agents and must be thoroughly dried and free of dust at time of application. All prepared surfaces must be brushed, air blasted and vacuumed to achieve a dust-free condition. No loose particles should be left on any of the substrate surfaces.

Saturant Coat & Fabric Lay-up Process: Priming Process

Sikadur®-330 serves as primer resin for the fabrics in wet application process. It is supplied in pre-batched units and larger bulk packaging. Mixing requires continuously mixing all of Part A in its container at low speed (max 500 rpm) then gradually adding all of Part B until fully homogeneous mix with uniform grey colour is achieved. Apply primer on prepared substrates with trowel, brush or roller.

Fabric Lay-up – Wet Application:

The Sika Wrap Sheet of 600gsm must be cut before application of Saturant into required sizes as per design. Distribute two-thirds of expected Sikadur®-300 quantity on clean PE sheet and place pre-cut fabric onto resin-covered sheet. Saturate SikaWrap® fabric by rolling with plastic roller in fibre direction until resin penetrates through fabric. Distribute remaining one-third of Sikadur®-300 onto fabric and evenly spread with roller to fully saturate. Remove excess resin. Place pre-wetted, saturated SikaWrap® 601C (600gsm product) fabric onto primed wet surface in required direction within open time of primer and smooth by hand to remove folds, creases and air entrapments. Overlapping pieces must be installed in same direction as fibres with 100mm overlap. No overlapping in weft direction (perpendicular to fibres) is generally required unless specified. After smoothing, laminate fabric onto substrate using plastic roller or squeegee working parallel to fibre direction until resin distributes evenly and all entrapped air is released. Avoid excessive force to prevent folding or creasing.

If additional layers are required, repeat impregnation and wrapping process. Application must take place wet on wet within 60 minutes of previous layer. Overlapping sections of additional layers should be distributed around circumference of column.

Quartz Sand Sprinkling and Protective

Plaster Just after completion of final coat of fibre wrap, Quartz sand shall be sprinkled over final coat of saturant to make key for protection Plaster. Alternatively screened coarse sand/stone granules may be used. The finished surface of CFRP application must be protected from external damages or fire using 15 mm thick protective plaster using Sikacrete 213F. Thermal Conductivity: approximately 0.14 W/m·K at +10°C. This protective plaster provides fire resistance and physical protection.

Table 7: Fabric Application Parameters

Parameter	Specification
Fabric Type	SikaWrap® 601C (600GSM)
Primer	Sikadur®-330
Impregnation Resin	Sikadur®-300
Overlap Length	100 mm (fibre direction only)
Application Time	Within 60 minutes (wet-on-wet)
Rolling Direction	Parallel to fibre direction
Additional Layers	Repeat process, distribute overlaps

Column Strengthening Case Integration

The CFRP strengthening system directly addresses the crack observed on column top due to laitance accumulation at basement-3. Previous repair methodology included 20mm MS plate installation, column top dismantling into four parts with re-casting using MCKRETE 90DS and MC DUR 1264-KFTR grouting. The CFRP application with 600 GSM carbon fiber wrapping now provides final strengthening layer, complementing mechanical plate installation and re-casting work. This integrated approach combines mechanical reinforcement, concrete repair, and fiber reinforcement for comprehensive column strengthening.

Figure 5: Column Strengthening by Carbon Fiber Wrapping

VIII. CONCLUSION

Summary of Comprehensive Implementation

The comprehensive column strengthening process successfully addresses the crack observed on column top due to laitance accumulation at basement-3. The systematic approach includes:

- Temporary Strengthening: Proper propping from B5 to ground floor with 40mm MS plate (E450MPa) ensures structural stability
- Anchor Quality: HIT-RE 500 V4 with 135mm embedment provides verified pull out resistance
- Material Performance: Emcekrete 90DS achieves M-90 N/mm² compressive strength consistently with 92 N/mm² average in core tests
- Sequential Casting: Eight-part casting with strength verification ensures proper continuity
- Quality Verification: Pull-out tests, core strength tests (92 N/mm² average), and weld tests confirm compliance
- CFRP Integration: 600 GSM SikaWrap wrapping with Sikadur primers/resins provides final tensile strengthening
- Protective System: 15mm Sikacrete 213F plaster with quartz sand key provides fire and damage protection

Key Implementation Success Factors

- Equipment Selection: TE-500 Hilti for lightweight concrete removal in confined spaces
- Anchor System: HIT-RE 500 V4 for superior bond strength in M24 anchors
- Grout Material: Emcekrete 90DS for non-shrink, high-strength structural repair
- Testing Protocol: Comprehensive pull-out, core strength (92 N/mm² verified), and weld tests
- Sequential Approach: Multi-part casting with strength verification between parts.
- Integration Planning: Coordinate concrete re-casting with CFRP application

Recommendations for Future Applications

- Maintain Equipment Standards: Use specified Hilti equipment for optimal performance
- Verify Anchor Bond Strength: Implement HIT-RE 500 V4 for all M24 anchor installations
- Specify High-Strength Grout: Use Emcekrete 90DS for M-90 N/mm² structural repair
- Conduct Comprehensive Testing: Perform all verification tests before CFRP application
- Implement Sequential Casting: Use multi-part casting with strength verification 6. Plan Integration: Coordinate all strengthening components for seamless implementation

References

[1] Structural Repair Techniques for High-Rise Basements, Journal of Construction Engineering, 2025

[2] Laitance Accumulation Effects on Column Performance, Concrete Research Quarterly, 2025

[3] CFRP Method Statement for RCC Strengthening, Sika Technical Guidelines, 2025

[4] Crack Propagation at Basement Interfaces, Structural Integrity Review, 2024

[5] High Flow M90 Grade Concrete Properties, Materials Science Today, 2024

[6] SikaWrap 601C Product Data Sheet, Sika Corporation, 2024

[7] Surface Preparation Standards for CFRP Application, Construction Engineering Journal, 2024

[8] Corner Rounding Requirements for Column Wrapping, Structural Integrity Review, 2025

[9] Quartz Sand Sprinkling for Protective Plaster Bonding, Construction Materials Review, 2025 [10] Fire Protection Mortar for CFRP Systems, Fire Safety Engineering Journal, 2024

[11] Equipment Requirements for Column Strengthening, Equipment Specifications, 2025

[12] Hilti TE-500 Light Weight Concrete Cutting Machine, Hilti Product Specifications, 2025.