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Comparative Design of Column for Different Strengthening Techniques (CFRP)

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Abstract - *Structures with the passing of time, they lose their strength because of various factors like improper maintenance, corrosion of steel reinforcement, poor construction exposure to harmful environments and improvement in design guidelines. These structural elements become statically unsafe. Enhancement of performance of such RC structural elements can be done by increasing strength and strength of structural elements can be increased by process of Retrofitting.*

As per the report of the rebound hammer test and core compressive test performed on columns at the 2nd and 3rd Floor levels, it was observed that total 56 numbers of columns have inadequate compressive strength as compared to their original design grade which was M40. Hence these columns require structural strengthening to achieve the required strength.

Key Words: CFRP, Retrofitting, Column Strengthening, RC Structural

1.INTRODUCTION

Retrofitting is defined as the process of modification of existing structures like buildings, bridges to make more resistant to seismic activity and other natural calamities. Structures with the passing of time they lose their strength because of many reasons like seismic activity, soil failure due to ground motion, arises problem like damaging of roof, foundation, walls, pillars, column and beams for these structures becomes statically unsafe and solution to these problem is Retrofitting. The structure performs normally during their life span but at the end of design period of structure, the structure may not be capable of taking load. Strengthening with Fiber Reinforced Polymers (FRP) composite materials in the form of external reinforcement is of great interest to the civil engineering community.

Orchid City Centre Mall is a commercial building located at Mumbai Central, Mumbai, Maharashtra. The building is an RCC-framed Structure. Years later the building experienced a fire at the 2nd and 3rd Floor levels. Further to the incident, the fire-affected areas were structurally assessed, the investigation includes the visual, non-destructive & destructive testing of the structural members in the fire-affected areas.

This proposal report comprises a structural strengthening scheme, design calculation, and construction methodology for the Columns.

2.METHODOLOGY

1. Surface Preparation

2. Forming Radius at Corners

3. Marking on The Surface

4. Drilling for Anchors

5. Applying R&M Primer Coating

6. Application of R&M Resin Putty

7. Cutting Fiber to The Required Length

8. Application of Carbon Fiber Wrap

9. Fixing of R&M Fiber Anchors, Top Coat, And Sand Sprinkling

10. Protective Coating

2.1 SURFACE PREPARATION

2.1.1 General:

Preparing the substrate surface (concrete, brick, steel, or timber) for effective bonding of the overlay is an important step in the methodology of CFRP Application. It includes various tasks like;

- Removal of loose/nonstructural layers such as CM plaster or Putty layers etc.
- Cleaning foreign deposits on the surface Leveling the undulations in the surface etc.

2.1.2 Objective of Surface Preparation:

The prepared surface will have the following advantages,

- It provides a leveled surface for FRP overlay because of which the voids due to undulations can be avoided.
- It provides a proper contact surface for the FRP while removing foreign deposits on the surface.
- It helps in bringing FRP composites direct in contact with the substrate material once removing nonstructural layers.

Figure 1: Removal of foreign deposits on the substrate surface

2.1.3 Tools Used:

- Mild grinder machine with cub wheel providing sufficient abrasion to the surface to remove all kinds of foreign deposits are used.
- Since it is a dry grinding process a blower machine is used to make the surface free from dust particles.
- To remove plaster works gentle chipper machine or manually operated hammer and chisel can be used.

2.1.4 Do's and Don'ts of surface preparation:

It is very necessary to ensure and also to take care of certain things in the process. The following are the factors to be ensured,

- Ensure the surface is free from dust
- Ensure the surface is free from water, the surface should not be wet in condition
- Ensure possible minimum undulations (no undulations in the ideal case)
- Person working should wear all safety belongings and safety hazards while performing at the site

2.2 FORMING RADIUS AT CORNERS

2.2.1 General:

Forming radius at corners is carried out for maintaining the better performance of the wrapping system. It is necessary to remove all the sharp corners with a grinder and form at least a minimum of 20 – 25 mm radius for better confinement in angular sections.

2.2.2 Objective for Forming Radius at Corners:

Rounded corner surfaces will have the following advantages;

- Rounding corners helps in making the composite action more effective.
- The efficiency of FRP confinement increases where the corners or edges have been rounded by forming a radius.

Figure 2: Checking the corners of the member with the Radius gauge

2.2.3 Tools Used:

- Mild grinder machine with cub wheel providing sufficient abrasion to the surface to remove all kinds of foreign deposits are used.
- Since it is a dry grinding process a blower machine is used to make the surface free from dust particles.
- Radius gauge is used to check the formed radius at the corner surface of the members.

2.2.4 Do's and Don'ts on the finished surface:

The following are the factors to be considered;

- The surface should be made free from dust.
- It should be overseen that there are minimal undulations.

2.3 MARKING ON THE SURFACE

2.3.1 General:

The marking should be done as per the design drawings provided. Before marking the surface, ensuring the surface is clean and dust-free is a must. Sometimes it is performed before surface preparation where only part of the structural member participates in strengthening.

2.3.2 Objective for Marking on the Surface:

Marking on the surface is carried out to maintain accuracy and avoid discrepancies in the work area.

Figure 3: Marking the area to be strengthened

2.3.3 Do's and Don'ts on the marked surface:

- Center to center distance between the laminates is also marked accurately.
- Follow the drawing given by the engineer to ensure the areas to be strengthened are measured and marked straight.
- In case of any obstacles, allowable shifting/change in the placement of FRP is pre-decided at this stage

2.4 DRILLING FOR ANCHORS

2.4.1 General:

The next step is to go for the drilling, for which marking has to be done at the center of the overlapping distance as specified (or) given in the drawing. The depth of the drilling is as per the size of fiber anchors which is almost 50mm to 60mm long. Thereafter, the fiber anchor is inserted inside the drilled area and the fiber is spread in such a way that it locks the joint of overlap.

2.4.2 Tools Used:

- Drilling machine is used to drill holes for fiber anchors.
- Since it is a dry drilling process a blower machine is to be used to make the surface free from dust particles.

2.4.3 Do's and Don'ts while drilling holes:

- It is strongly recommended to use safety equipment like safety goggles, nose mask & hand gloves while carrying out the work.

Figure 4: Drilling on concrete surface

2.5 APPLYING R&M PRIMER COATING

2.5.1 General:

Primer is a resin-based material it is applied by brush or roller. Primer provides a compatible surface for the overlay and thus improves the bonding of the strengthening material.

2.5.2 Objective of application of Primer:

To promote adhesion and prevent the surface from drawing resin from the FRP, a low-viscosity epoxy primer compatible with the substrate is applied with a roller until the substrate is locally saturated. It also helps in filling those small voids on the substrate surface.

2.5.3 Tools Used:

- Stirrer Machine is used to mix the base and hardener of the Primer.
- Primer is applied on the marked surface of the area to be strengthened with a brush.

2.5.4 Do's and Don'ts while applying Primer:

- The PRIMER is a chemical product and care should be taken during its handling. It is strongly recommended to use safety equipment like safety goggles, nose mask & hand gloves while handling and using the specific product.
- Any contact with the bare skin should be avoided. If the paste does come in contact with the bare skin, it can be easily treated with splashes of water and cleaned.

Figure 5: Primer application on the marked surface to be strengthened

2.5.5 Conclusion:

After application of **Primer** allow the layup to cure generally recommended for 12 hrs may vary depending on the environmental conditions.

2.6 APPLICATION OF R&M RESIN PUTTY

2.6.1 General:

The surface is well prepared with putty/leveling mortar to fill the undulations or unevenness. It should be overseen that the surface of the member to be strengthened is smooth, even, and free from undulations for the efficient working of the CFRP composite.

2.6.2 Objective for Application of resin putty:

Application of putty or leveling mortar is carried out to maintain uniform surfaces without any voids and undulations.

2.6.3 Tools Used:

Putty should be applied using a spatula to cover the unevenness and any undulations.

Figure 6: Putty application on the surface to be strengthened

2.6.4 Do's and Don'ts while applying putty/leveling mortar:

- It is strongly recommended to use safety equipment like safety goggles, nose mask & hand gloves while carrying out the work.
- Resin putty is a non-structural element hence its thickness is limited. Generally suggested 5mm

2.7 CUTTING FIBER TO THE REQUIRED LENGTH

2.7.1 General:

In a clean area away from the resins, the **fabric (R&M Carbon Fiber)** is carefully measured and cut by the specifications. Care should be taken so that there isn't any damage to the carbon fabric.

2.7.2 Dos and don'ts while handling the fabric:

- Fabric should be cut in a clean place free from dust.
- Fibre should not be damaged by any means before and after its application.
- Fibre should be stored at ambient temperature at the site.

Figure 7: Showing cutting of carbon fiber

2.8 APPLICATION OF CARBON FIBRE WRAP

2.8.1 General:

R&M SATURANT is a bonding agent for the fibers and it is a 2-component-based material. Base: 3.7kg - Hardener: 1.3kg. These 2 components require proper mixing with the help of a Stirrer machine for at least 2-3 minutes for accurate merging which gives an output of superior bonding. Immediately after stirring it should be applied on the surface without any time gap with the help of brush application.

Apply **R&M Fiber** immediately after applying the **R&M SATURANT** layer. We must start doing fiber wrapping around the surface as per the guidelines of the manufacturer concerning the design given. While wrapping roller application with nominal hand pressure is a must so that the fiber should get properly embedded in the epoxy for superior bonding with concrete which results in developing better strength. After the application of Carbon fiber, seal it with another layer of saturant.

Laying up additional CFRP L-wrap on the four edges of column for absolute confinement.

Note: Refer drawing for CFRP specification and detailing.

2.8.2 Objective of fiber wrap:

They serve as additional reinforcement in the structural members when applied with suitable bonding resin. Hence, they can be used in shear strengthening of beams, confining columns for their axial capacity, strengthening horizontal members for their flexural capacity in passive mode, and also improving resistance towards uni-axial/bi-axial moments in columns.

2.8.3 Do's and Don'ts while applying fiber wrap:

- It is strongly recommended to use safety equipment like safety goggles, nose mask & hand gloves while carrying out the work.
- Avoid creases and air pockets while applying the carbon fiber wrap to the area marked to be strengthened.
- Use a Teflon roller to expel entrapped air in the fiber.

Figure 8: Showing the application of carbon fiber wrap

2.9 FIXING OF R&M FIBER ANCHORS, TOP COAT, AND SAND SPRINKLING

2.9.1 General:

After completing the wrapping work fiber anchors are applied at specified spacing on columns. The anchor is inserted in the drilled hole as shown in the figure and then protruding fibers are manually spread in a circular shape so that it should give a locking effect from all 360°.

2.9.2 Reason for fixing fiber anchors:

The purpose of placing a fiber anchor is to hold the ends & joints of the wrap. It also helps in bringing FRP composites in contact with core concrete/substrate.

Figure 9: Showing fixing of carbon fiber anchors and top coat of our cafe.

2.9.3 Do's and Don'ts while fixing fiber anchors:

- It is strongly recommended to use safety equipment like safety goggles, nose mask & hand gloves while carrying out the work.
- Brush the threads well before using.
- Spread the fibers at 360o to give a locking effect all around.
- Use sufficient saturant during its application

2.10 PROTECTIVE COATING

2.10.1 General:

It is advised to provide fire protection coat post strengthening on the structural member to fire-proof the members. Fire protective coat also helps as UV resistant for the structural member after strengthening.

Figure 10: Showing member with fire protection coating after strengthening.

2.10.2 Materials for Application:

Cement, Vermiculite powder, Sand, Plastering Accessories-Metal Lath, angle beads, special pieces for internal angles and corners, Trial mix.

2.10. 3 Preparation:

Clean the surface and remove any dust, removing loose material and substances that may impair the work. Form ties and other obstructions shall be removed or trimmed back even with the surface of the solid base.

Before vermiculite plastering starts, dampen, by spraying water on concrete dash coat surfaces that are to receive plaster with clean water.

2.10.4 Material Mix Proportion of Plaster:

Cement 1 Part: Vermiculite powder 1 part: Sand 3 part

2.10.5 Application of Plaster:

Plaster shall be prepared in mix 1:1:3 (1-part cement, 1-part vermiculite powder & 3-part sand) using sufficient water to produce a workable consistency. Plaster by first mixing with water (30%). After all the ingredients have been added including the remaining mixing water, the plaster should be mixed for a further few minutes until uniform vermiculite dispersion.

The first coat shall be applied with sufficient material and pressure to ensure tight contact with a strengthened surface of 12 mm thick. The surface of the second coat shall be brought to a true, even plane with a rod or straightedge, filling surface defects in place with plaster of thick 8mm. Making a total thickness of 20 mm.

Applied plaster shall be floated as smoothly as possible and steel-trowelled. Steel trowelling shall be delayed as long as possible and used only to eliminate the uneven points and to force aggregate particles into the plaster surface. Each plaster coat shall be applied to an entire strengthening surface or ceiling panel without interruption to avoid cold joints and abrupt changes in the uniform appearance of succeeding coats.

2.10.6 Curing:

Provide sufficient moisture in the plaster by spraying water as frequently as required at least twice per day for 7 Days.

3. RESULT:

Table -1: Test Report of Concrete Cylinder **(Plain)**

Test Report of Concrete Cylinder			
Cylinder ID. Mark	Cylinder WT (kg.)	Crushing Load (KN)	Crushing strength (N/mm^2)
Plain 1	14.653	496.8	28.13
Plain 2	14.762	388.0	21.97
Plain 3	14.599	433.7	24.55

Table -2: Test Report of Concrete Cylinder **(300GSM)**

Test Report of Concrete Cylinder			
Cylinder ID. Mark	Cylinder WT (kg.)	Crushing Load (KN)	Crushing strength (N/mm^2)
300GSM_1	14.826	878.20	49.72
300GSM_2	14.925	702.7	39.78
300GSM_3	14.840	875.8	49.59

Table -3: Test Report of Concrete Cylinder **(400GSM)**

Test Report of Concrete Cylinder			
Cylinder ID. Mark	Cylinder WT (kg.)	Crushing Load (KN)	Crushing strength (N/mm^2)
400GSM_1	14.734	856.6	47.88
400GSM_2	14.855	895.5	50.70
400GSM_3	14.962	888.9	50.33

Table -4: Test Report of Concrete Cylinder **(600GSM)**

Test Report of Concrete Cylinder			
Cylinder ID. Mark	Cylinder WT (kg.)	Crushing Load (KN)	Crushing strength (N/mm²)
600GSM_1	15.174	1521.0	86.11
600GSM_2	15.170	1479.0	83.74
600GSM_3	15.315	1581.0	89.51

EXPERIMENTAL RESULTS

Sample ID	Avg. Load	Avg. strength
Plain	439.5	24.88
300GSM	818.9	46.36
400GSM	876.67	49.63
600GSM	1527	86.45

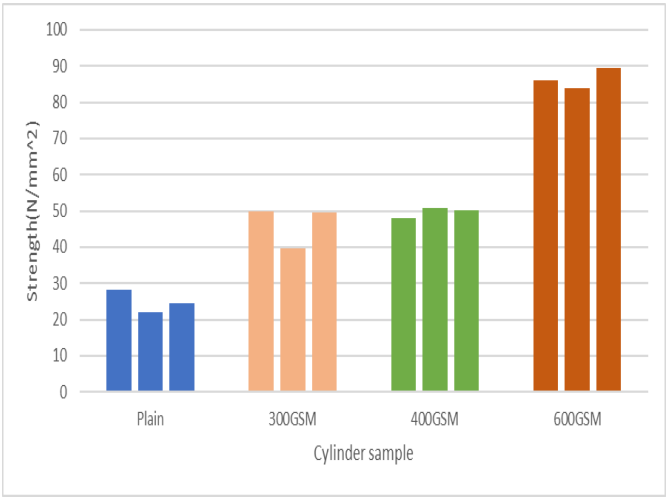

Chart. 1. Different Cylinder Sample

From above graph it is seems that 600GSM sample gives maximum strength as compare to another sample.

Plain sample of M30 grade at 70days with various

4. CONCLUSIONS

We From experimental work and testing of specimen following conclusions have been concluded:

i. After 70 day concrete attaining highest compressive strength when 600GSM carbon fibre rapping increase compressive strength of 61.57 N/mm2 as compare to plain concrete column casting.

ii. After 70 day concrete concrete attaining highest compressive strength when 600GSM carbon fibre rapping increase compressive strength of 40.09 N/mm2 as compare to300GSM column cylinder.

iii. After 70 day concrete concrete attaining highest compressive strength when 600GSM carbon fibre rapping increase compressive strength of 36.82 N/mm2 as compare to400GSM column cylinder

iv. Further I conclude that 600GSM is giving maximum strength as compare to all other type of casting.

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