

STRUCTURAL REMEDIATION & RETROFIT OF DISTRESSES PRECAST-PRESTRESSED 'T' BEAMS OF A PUBLIC UTILITY BUILDING, IN COLOMBO, SRI LANKA. – A SITE CASE STUDY.

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ABSTRACT: The roof slab of a portion of a government public utility building situated in Colombo, Sri Lanka, comprises of precast – prestressed 'T' beams. There was a huge fire in this building and during the subsequent refurbishment of the building it was noted that the majority of the 'T' beams at this area were exhibiting distresses in the form of cracks. A thorough investigation conducted by the concerned authorities in conjunction with the University of Moratuwa concluded that the structural distress was due to event overloading onto the roof slab during the fire fighting operations. It was also concluded that a requirement of certain remediation and retrofit measures to the distressed elements were necessary to bring the 'T' beams back to their intended service performance level. This paper describes in detail the site case study of the repairs and retrofit that was carried out to achieve the desired design objective. Repairs to cracks were carried out using multi-port, low pressure resin injection, the retrofit was carried out using the Carbon Fibre Reinforced Polymer (CFRP) system, thus resulting in a quick, discreet and cost effective way to meet the design objective.

1. INTRODUCTION

Project description

A prominent and critical public utility building of a government department situated in the central business district of Colombo, Sri Lanka comprises of the front tower portion of basement + ground + 14 upper floors and a rear portion rising 4 floors high (Figure 1). The building is a typical reinforced concrete column beam primary framed structure with precast-prestressed type 'T' beams acting as the secondary grid infill. The building was subject to a huge fire on the night of 20th February 2009, after an airborne incursion was shot down and crashed into it. Fire fighting operations were carried out to bring the blaze under control. Subsequently, a major refurbishment effort was initiated to bring the building back to functionality.

During this refurbishment exercise, it was noticed that a majority of the 4th floor (roof floor) 'T' beams of the rear portion of the building were exhibiting structural distress in the form of cracks.

Need for structural remediation

The distresses to the prestressed-precast beams in the form of cracks were jointly investigated by the concerned authorities and academicians of University of Moratuwa. The cracks observed were typical flexural crack patterns as shown in Figure 2. The details of the structural investigation and repair retrofit design are not in the scope of this paper and hence are not elaborated upon herein. Briefly, the structural investigation concluded that the distresses in the form of cracks to the beams was due to the impact and event overloading caused by the evacuation of various bulky office equipment from the upper floors of the tower portion onto the roof of the lower rear portion, during the firefighting



Figure 1. : *Rear façade view of the public utility building.*



Figure 2. : View of beams showing typical flexural crack patterns.

operation. The investigations also deemed it necessary to carry out appropriate repair and retrofit measures to bring the distressed beams back to a satisfactory service level.

2. STRUCTURAL REPAIR & RETROFIT DETAILS

Structural repair & retrofit objective

To appropriately address this particular issue at hand, the objective was first determined. The objective was two pronged viz. restoring the structural integrity of the cracked beam elements i.e. repair and thereafter bring about enhancement in the flexural capacity of the repaired beams i.e. retrofit. Out of the various available repair and retrofit options available the most feasible options were explored and short listed to the following based on various criteria:

- The repair / retrofit technique and its feasibility to the current scenario.
- Level of intrusion of a particular technique onto already distressed elements.
- Performance of the repair / retrofit technique with respect to the current scenario.
- Time and cost aspects vis-à-vis other methods.

In view of the above criteria it was imperative that the repair and retrofit system to be put in practice should be non-intrusive, quick, discreet and one which does not impose any additional loads onto the elements. The use of conventional techniques such as concrete jacketing or steel plate bonding for retrofit had been ruled out because of their invasive, time consuming process and additional dead loads. Thus, the repair technique recommended was surface mounted, multi-port low viscosity epoxy resin injection into the cracks, whilst the retrofit technique recommended was carbon fibre reinforced polymer (CFRP) wrapping.

Repair & retrofit basis

Out of the thirty five beams, four outer beams on each side of the building were found to be without any cracks. These beams were considered to be structurally sound and needing no remedial measures. The central eleven beams exhibited the most severe structural cracks whereas the remaining beams were having minor cracks. The repair process required injection to all such beams exhibiting cracking. Two separate CFRP retrofit schemes / details were designed for the central twelve beams categorized as severe cracking and the other remaining beams categorized as minor cracking. CFRP wrap details are given in Figure 3.

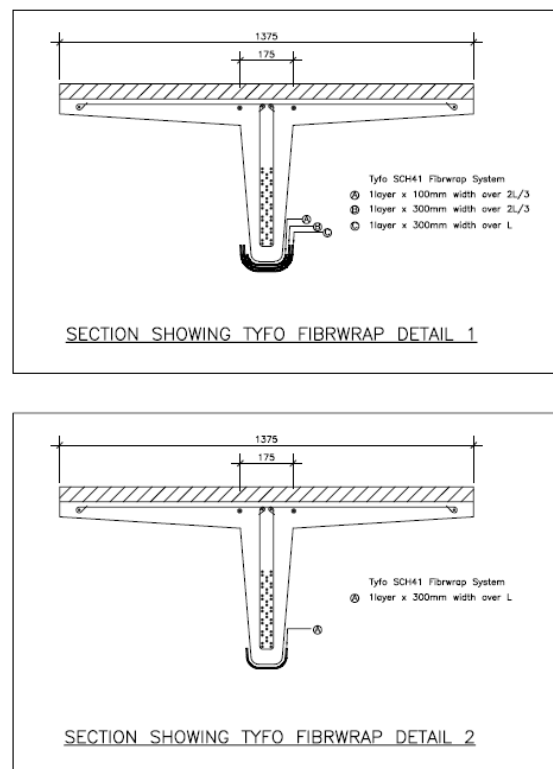


Figure 3. : CFRP wrapping details

Crack injection resin properties

An appropriate crack injection resin was selected based on the following physical and mechanical criteria;

- Viscosity low enough to have good penetrability into hair line cracks.
 - Pot life long enough to facilitate the proposed low pressure, surface mounted, multi port injection technique.
 - Good mechanical properties such as bond strength, tensile strength, slant shear strength.
- The salient properties of the injection resin used for carrying out the crack repair works are as shown in Table 1.

Table 1. *Properties of injection resin used for crack repair.*

Property	Test Method	Typical Value*
Mix viscosity		200cps @ 25°C
Pot Life		85 minutes @25°C. 21 minutes @40°C.
Tensile strength	ASTM D-638	62.1 MPa
Wet Slant shear strength	AASHTO T-237	Cement mortar failure.
Compressive strength	ASTM D-695	110.3 MPa.

* Values reported by injection resin manufacturer in technical datasheet.

CFRP system properties

The CFRP system selected for use was a proprietary system from a reputed CFRP system manufacturer. This system selection was based on the criteria of material characterization, system performance and environmental durability considerations. The CFRP system comprised of a unidirectional carbon fibre fabric as the reinforcement and a compatible two component epoxy resin as the matrix. The key properties of the CFRP system used for carrying out the structural retrofit are as shown in Table 2.

Table 2. *Properties of CFRP system used for retrofit.*

Property	Test Method	Typical Test Value*
Ultimate tensile strength	ASTM D-3039	986.0 MPa.
Elongation at break	ASTM D-3039	1.0%
Tensile modulus	ASTM D-3039	95.8 GPa.
Laminate thickness		1.0 mm

* Values reported by CFRP system manufacturer based on gross laminate properties.

3. STRUCTURAL REPAIR & REMEDIATION PROCESS

Repair & retrofit sequence

The repair and retrofit sequence adopted was as follows:

- Identifying on site and demarcating the various categories of beams viz. beams requiring no intervention, beams requiring crack repairs & detail 1 CFRP wrapping and beams requiring crack repairs & detail 2 CFRP wrapping.
- Carrying out repairs to cracks by low pressure, low viscosity multi port epoxy resin injection.
- Carrying out CFRP wrap installation onto beams.

Repair with injection of cracks

The crack injection works comprised the following activities:

- The crack lines on the beams were identified and demarcated.
- Paint, surface finishes and other deleterious materials were removed by means of wire brushing or grinding to clean the crack line.
- Injection port locations along the crack line at appropriate spacing were then marked.
- Surface mounted injection ports were then fixed along marked locations with epoxy putty.
- The rest of the crack line was sealed with cementitious non-shrink grout.
- The two parts of epoxy resin were mixed in small batches according to the mix ratio as specified by manufacturer.
- The low pressure auto injector syringes were then filled with the mixed resin and fixed onto the installed port for auto injection.
- The auto injector syringes were replenished with fresh resin mix as and when they were depleted.
- Injection for a crack line continued until all the ports no longer accepted any more resin.
- Injected resin was allowed to cure and the ports were then removed.

Figure 4 shows the crack injection process.

Retrofit with CFRP – the preparatory work

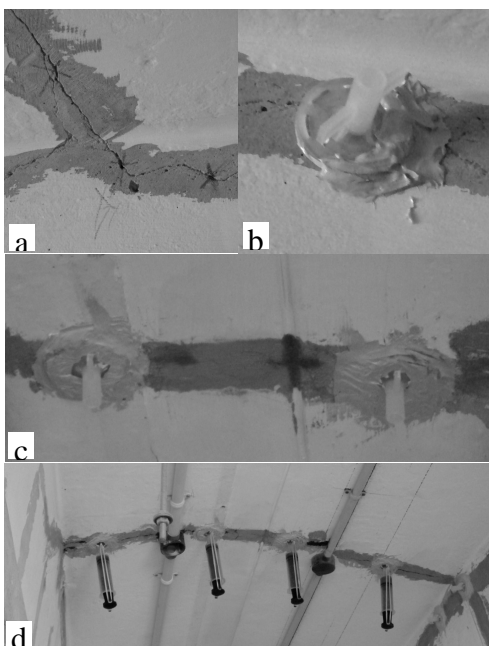


Figure 4: a) marking port locations. b) & c) fixing surface ports with epoxy putty. d) low pressure, multi port epoxy resin injection.

The preparatory works for retrofit process comprised of the following activities:

- Beams requiring the appropriate type of wrap detail were first identified and demarcated on site.
- The areas of wrapping (beam soffit and some portion of the side faces) were then ground off using diamond cup grinders to remove paint and make the surface free of protrusions.
- The ground surface was then air cleaned and localised punning with polymer modified cementitious skim coat was carried out to fill up small pin holes, undulations and surface defects to make the surface fairly smooth.
- After adequate water curing, the surfaces were then sanded using sand paper to smoothen out any fine protrusions thereby making the surface ready to receive CFRP application.

Retrofit - CFRP Wrap Installation

The installation of the CFRP was wet wrapping type process as recommended by the system manufacturer. The installation process comprised of the following activities;

- The carbon fibre fabric was sized and cut to the required dimensions that were obtained from site measurements.
- The two components of the saturant resin matrix were mixed together in the ratio as per manufacturer's specifications.
- Sized fabric was then manually saturated from both sides with the mixed resin matrix.
- Saturation was carried out manually using fabric rollers.
- The saturated fabric was then rolled onto spools and taken to site for installation.
- Prior to installation of the CFRP wraps, the prepared surface was first wet primed with a coat of saturant resin.
- The saturated fabric was then installed onto the primed surface by evenly rolling out the spool along the primed surface.
- The CFRP strips were adhered onto the surface using uniform hand pressure along the main fibres, thus ensuring removal of any entrapped air voids behind the CFRP wrap.
- Additional layers were installed on wet strips to build up to the required number of layers as specified.

Figure 5 shows the CFRP installation process.

4. CONCLUSION

The use of CFRP for structural retrofit of the distressed beams of the building was found to be an appropriate technique to achieve the desired objective and at the same time being minimal invasive, quick and discreet as compared to conventional strengthening techniques. The adoption of this technique led to saving of beam that would otherwise needed demolition.



Figure 5. A) sizing carbon fibre fabric. B) installing saturated fabric onto element.

References

- ACI Committee 440R, *Guidelines for the design and construction of externally bonded FRP system for strengthening concrete structures*. American Concrete Institute, Detroit, 2000.
- ICC AC125, *Interim criteria for concrete and reinforced and unreinforced masonry strengthening using fibre reinforced polymer (FRP) composite systems*. ICC Evaluation Service Inc. Whittier, California, 2003.
- Technical Datasheet, *Tyfo® SCH41 composite using Tyfo® S epoxy*. Fyfe Co. LLC, San Diego, CA. 2006.
- Technical Datasheet, *Tyfo® 111 Low viscosity injection epoxy*, FYFE Co. LLC, San Diego, C.A. 2009.
- Technical Specifications, *Tyfo® systems installation guidelines*, FYFE Co. LLC, San Diego, CA. 2009.