Construction of a high-rise commercial building using CFT technology in Mumbai, India

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Abstract— The paper emphasis on an introduction and implementation of Concrete Filled Tubes (CFT) as a modern structural technology, which benefits advantages of both steel and concrete structures simultaneously. One of the main advantages to introduce CFT is the interaction between steel tube and concrete. Occurrence of the local buckling of steel tube is delayed by the restraint of concrete and the strength of concrete is increased by the confining effect provided from the steel tube simultaneously Concrete Filled Tubes (CFT) is a technology which helps for faster construction with high structural strength. CFT is a composite construction which uses steel as its out periphery and concrete filled inside it, hence the tensile load is taken care by steel and compression load by concrete. It helps in increasing ductility with more slender columns and controlling buckling of column. The intention of this is to make an understandable process ready for engineers to help them understand the use of CFT technology in construction, showing various connections of column to column, column to beam, primary to secondary beam and metal deck slab with beams.

In Past, Extensive research work has been done in Japan over the last 15 years, including "New Urban Housing Project" and "US-Japan Cooperative Earthquake Research Program, in addition to the work done by individual universities and industries, which has been presented at the annual meeting of Architectural Institute of Japan (AIJ). Here authors introduce the Speed, merits, design provisions and recent construction trends of CFT column systems introduced very first time in Mumbai by L&T Realty developer of the project on one of the prestigious and high-rise commercial project – L&T Business Tower which was constructed by India's No. 1 construction company L&T Construction, and discusses the results of CFT structures which have been carried out to look for the advantages in the performance and construction cost compared which other constructional system. The work included constructing a high-rise commercial building in the busy roads of Mumbai using CFT technology.

The author is a project team leader taking ownership of constructing a commercial tower using CFT which helped him to save a huge amount of construction time. This paper also introduces the advantages, challenges faced, methodologies used, construction work procedures followed, QA/QC, NDT examination manpower analysis and time saved in constructing Mumbai's high-rise commercial building using CFT technology.

Index Terms— L&T, Concrete Filled Tubes, CFT Technology, Structural Steel, Fast Construction

1 INTRODUCTION

Concrete Filled Tubes (CFT) is the modern composite technology which uses both steel and concrete as its integral part and thus forms a high strength structure for construction. The concrete takes care of the compression load part whereas the steel takes care of the tensile load. In 1993, a five-year research project was done on composite and the hybrid structure started in the fifth phase of US japan cooperative earthquake research program, and the CFT columns were introduce in that program. Research findings obtained from this project formed present design recommendation for CFT columns.

This paper will include the process of fabrication of CFT columns, challenges faced, advantages, methodology used, manpower analysis, erection methodology and time saved using CFT technology in constructing a high-rise commercial tower in Mumbai, India.

The configuration of the building is 1 Basement + 2 Podiums + Ground + 15 Floors + Terrace, comprising of the total build up area of 10.6 Lakhs sqft and floor plate of 33000 sqft.

2 Pre-Construction Tasks

2.1 Logistic Challenge

Logistics is always a challenge for the densely Populated city like Mumbai, which is a financial capital of India. Mumbai being an Island city; has always scarcity of Land Parcel & this had led to High Rise Construction in the city. The site is in the heart of the city & opposite to one of the busiest roads of the City called JVLR. The shape & Plot geometry had left hardly any road widths for the Movement of Vehicles & it was very difficult for managing the logistic issues. There was not sufficient space in building yard for carrying out different activities.

2.2 Fixed Deadline

The target given was to complete the building within 27 months right from excavation till interior fit outs and handover.

2.3 Difficult Soil Condition

The soil investigation report revealed that Basalt rock of very high compressive strength is found at an early depth of 2 mts from natural ground level.

3 Methodology

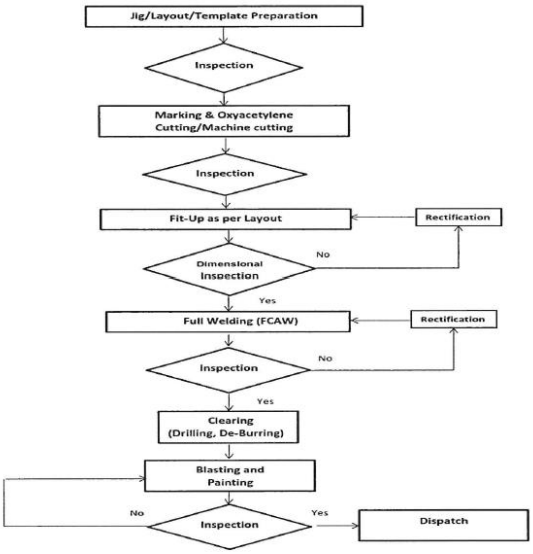
The bore logs revealed the presence of high-density basalt rock at very early depth of 2m. We realized that we have to excavate approximately 1.5lakh cum of rock which means approximately 22000 truckload of hard basalt rock. 25 excavators were started working on project site and when we realized that the same is not helping the purpose, then controlled blasting was deployed to expedite the excavation process. Further, to protect the soil on one side & the only available route for logistics on other side, we had to carry out shore protection work using 1500 micro-piles which was successfully completed in 90days.

We started excavation activity in January 2018 and the building is to be inaugurated latest by Sept 2020. Keeping in view the nature of rock, the monsoon & statutory constraints we realized that no matter which technology we use for excavation the same is going to consume at least 7 to 8 months for excavation. This challenge was understood immediately after geotechnical investigation was completed in September 2017 and we started discussing a change from RCC to steel structure; however, it was a little early to conclude and move towards Steel structure.

It was towards early October 2017, when we concluded that we are not going to get any additional time to complete the project and no matter what the buildings must be up & running by Sept 2020, we seriously started thinking about the steel building option to overcome the time delay in excavation. L&T's internal design wing i.e. EDRC (Engineering Design and Research Centre) design team started working with steel framing along with metal deck slab which resulted in considerable time saving of approximately 4 months. This resulted in slab cycle time of 10-15 days. We also opted for double height concrete filled tube columns (CFT columns) which further helped to reduce the time spent on conventional RCC columns and walls. The prefabricated steel framing also reduced site activities to greater extent. Most importantly when we were carrying out our excavation simultaneously the CFT columns and beams were getting fabricated in shop.

4 Fabrication Of CFT Columns

The following process diagram shows how the fabrication process was done, also the number of inspections done in the process to maintain the quality of the product.



4.1 Raw Material Selection

All the raw materials shall be used approved make & Spec only. And inspected thoroughly prior to release for fabrication. Quality Assurance (QA) engineer shall carry out raw material inspection in accordance with requirements of the plan, technical specification & applicable code and standards. Only materials accepted by QA engineer shall be released for fabrication.

If the raw material is not meeting the technical specification & as per plan (Based on the customer requirements), QA/QC department shall reject the material and re-sent back to supplier.

The raw material brought to site was of E350 grade.

4.2 Electrodes To Be Used

The approved make shall be used for all welding processes i.e. Gas Metal Arc Welding (GMAW), Flux-Cored Arc Welding (FCAW) and Shielded Metal Arc Welding (SMAW).

Electrodes for electric arc welding shall confirm to IS: 814 (Part 1 & 2)/ASME. E 7018 /E6013 shall be used for SMAW. All Low hydrogen electrodes (E7018) shall be baked and stored before use as per manufacturer's recommendations. The electrode shall be re-baked at 250°C - 300°C for one hour and later cooled in the same oven to 100°C. It shall be transferred to a holding

oven maintained at 60°C - 70°C. The electrode shall be drawn from this oven for welding). ER-71T1C (0 0.8mm to 1.2mm) shall be used for FCAW.

4.3 Making Of Layout

Experienced (Skilled fitters) persons only should prepare the JIG/Layout Template. In order to prepare the Layout Template, ensure that the ground surface (where the JIG/Layout is placed) should be in level. Then prepare the JIG/Layout with permanent welding by maintaining the dimensions as per approved GFC & Shop drawings. Templates for middle rafter and side columns should be prepared by steel sheet as per approved drawings.

4.4 Marking, Cutting And Drilling As Per Layout

Once the JIG/Layout/Template is cleared by quality team, and then proceed with raw material marking, cutting & drilling as per dimensions given in the Good For Construction (GFC) & Shop drawings.

4.5 Fit-Up And Welding

Accepted JIG/Layout only shall be used for fit-up (Fabrication) of plates, columns and UB Sections. Place the plates/sections in the approved JIG/Layout as per GFC/Shop drawings and join the members with tack weld. Check the dimensions as per GFC drawing. And maintain the inspection report. Job number, Part mark number and Part mark serial number shall be hard punched on each and every Built-up member. The size of the punches shall not be less than ½ inch. This punching will be done at Fabrication stage. If the dimensions are matching with the GFC drawing, proceed with full welding. Full (Final) welding shall be done with approved WPS & Qualified welders only for the processes of GMAW, FCAW & SMAW. Full welding is used to be done using automatic welding machine. Scale, slag, rust, oil, moisture, and other contaminations shall be removed from the surface and surrounding areas of base metal. There are various checklist maintained at each stage of fabrication process, such as: raw material inspection report, in process inspection report, weld visual report, fit-up inspection report and final dimension inspection report.

4.6 Non-Destructive Test Examination

Dye penetration test (DPT): DPT is a low-cost testing method and is widely used for checking of surface breaking defects in all non-porous material. The testing will show us defects such as hairline cracks, surface porosity, leaks in new product, etc. Following is the test certificate issued after testing:

DYE PENETRANT EXAMINATION REPORT

D.P.No:36
Date:19/06/2018

Project	017176- L&T BUSINESS TOWER (PHASE-1) PROJECT, At POWAI (WEST), Mumbai.	Job No.	017176
Client	L&T Realty	Sub-Contractor	CLIFFKUMAR ENGINEERING PVT.LTD
Main Contractor	L&T Construction, B&F		

Details of Testing: FILLET WELDS

Method	SOLVENT REMOVABLE METHOD	Acceptance Criteria	AWS D 1.1 : 2015
Type of LPT	VISIBLE CONTRAST	Pre-Cleaning	Solvent cleaning
Dwell Time	10 min	Development Time	10 min
Test Temperature	Ambient	Post Cleaning	Solvent cleaning
Examination Code :	ASTM-E-165	Material Specification :	IS2062 E350 BR

Details of LPT Chemicals used:

Sl.No.	Description	Make	Batch No.	Expiry Date
1.	Penetrant	PREDEEP MATEL	6807	DEC-19
2.	Cleaner	PREDEEP MATEL	6872	FEB-20
3.	Developer	PREDEEP MATEL	6711	AUG-19

DRG NO:-DWD-1208-LTR-EDRC-L&T-FB-S2-7B.1 MARK NO:-C7B-1

Part Mark	Observations	Interpretation	Result	Remarks
PB2-BP.T+P16-S3	No Indication Found	Accept	Ok	
PB2-BP.T+P1,P2,P3 & P4	No Indication Found	Accept	Ok	
P16-S3+P1,P2,P3 & P4	No Indication Found	Accept	Ok	

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared and tested in conformance with the requirements of AWS D 1.1/D1.1M : 2015 Structural Welding Code - Steel, surface

For LTC
Witnessed By
Date
[NDT Level II]

For CKEPL
Examined Manoj N.Gole
Date 19/06/2018
[NDT Level II]

Ultrasonic test (UT): This test is based on the propagation of ultrasonic waves in the object or material tested. In most common UT applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials. Following is test certificate issued after testing:

ULTRASONIC TEST CERTIFICATE

REPORT NO: **TNDTS/NSFPL/14467/18-19 UT** DATE: **31.08.2019**

CLIENT: **M/s. LARSEN & TOUBRO LIMITED, L & T Reality, Gate No. 3, Powai, Mumbai. 400076**

OBJECT OF TEST: **To find out Internal Defect.** INSPECTION DATE: **30/08/2019**

MATERIAL SPECIFICATION: **M. S. IS 2062 Gr. E350, Thickness - 12mm, Between Part- 7 to 8, Column No. C7A, C6A, C1N, Butt Weld Joints, (03Nos)**

TEST SITE: **AT L&T Gate No-03, Powai, (Contractor Worked- M/s. P. S. Nair)**

EQUIPMENT (UFD) Microscan Einstein II (TFT) — EQUIPMENTS SPEC: **ASTM E-317**

EQUIPMENT SR. NO: **E2711-1010** — EQUIPMENTS CALIBRATION DUE ON: **09/01/2020**

BASIC CALIBRATION BLOCK: **IIW-V2 Block,** — REFERENCE CAL BLOCK: **Having 19mm SDH Block**

	Sr. No.	FREQUENCY	SIZE	TYPE
PROBES USED	(1)	4MHz	8X9mm	60°, 45°Angle Probe

RANGE CALIBRATION:	(1) Normal Beam Probe. mm	(2) Angle Beam Probe.0- 100mm
	(3) TR Straight Probe. mm	(4)

GAIN USED: **DAC Plotted 80% FSH on 55dB** — SENSITIVITY: **+6 dB**

METHOD: **Pulse – Echo Contact Testing** — COUPLANT: **Oil,**

SCANNING: **½ Skip to 1 ½ Skip Distance from Butt Weld Centre +10% overlap**

STAGE OF INSPECTION: **Final Stage of Welding** — SURFACE CONDITION: **As Smooth - Satisfactory**

TEMPERATURE: **Ambient** — TEST LIMIT: **100% of weld area**

STANDARD SPECIFICATION: **ASME Sec VIII, Div I, App-12, Cl 12.2 & 12.3**

ACCEPTANCE CRITERIA: **Any Defect Echo above DAC Reference level shall be not Acceptable**

NAME OF OPERATOR: **MD. MINHAJ (ASNT Level – II, UT, MPT, LPT)**

DIMENSION AND RESULT:
(03Nos) M. S. Butt Weld Joints of Column were offered for Ultrasonically Test. The details are as below.

S/No	Item	Column No	Dimensions	Qty.	Remarks
01.	Between Part 7 to 8	C7A	900mm x 750mm x 12mmThk	01Nos	Satisfactory
02.	Between Part 7 to 8	C6A	900mm x 750mm x 12mmThk	01Nos	Satisfactory
03.	Between Part 7 to 8	C1N	1100mm x 600mm x 12mmThk	01Nos	Satisfactory

OBSERVATION:- (1) No recordable discontinuity indications were observes at above DAC Reference level at this stage of inspection by this technique in above mentioned all (03Nos) Butt Weld Joints of Column.

REMARES:- (1) The above mentioned all (03Nos) Butt Weld Joints of Columns were found to be Satisfactory.

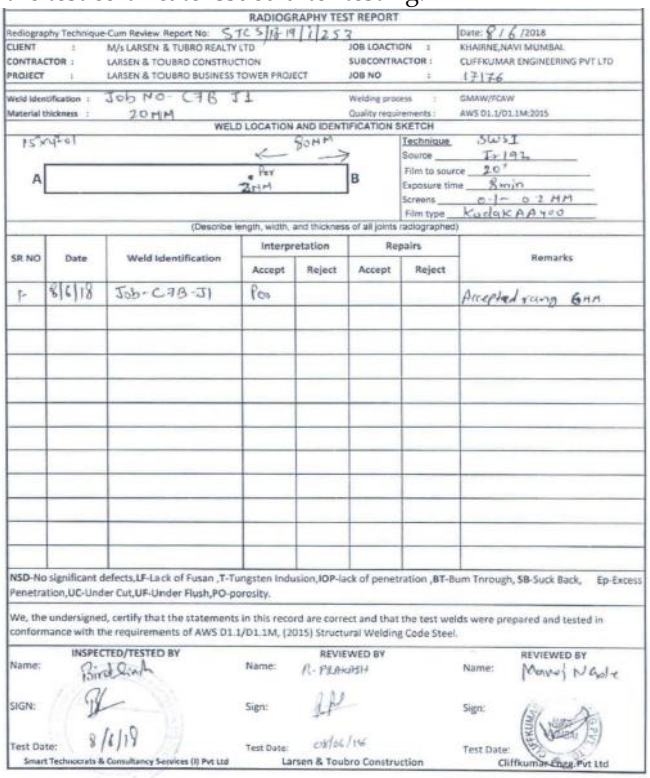
WITNESSED By: Mr. S. Sivaperumal For M/s. Larsen & Toubro.

For Client: Name: Sign & Seal

For TPI: Name: Sign & Seal

For Technocraft NDT Services Name: Sign & Seal

Radiographic test (RT) : Industrial Radiography is performed in utilizing either X-rays, produced with an X-ray generator or a Linear particle accelerator, or gamma rays generated by the radioactivity of isotope sources. After crossing the specimen, photons are captured by a detector, such as a silver halide film, a phosphor plate or flat panel detector. Following is the test certificate issued after testing:



RADIOGRAPHY TEST REPORT

Radiography Technique-Cum Review Report No: STC 5/18.19/1253 Date: 8/6/2018

CLIENT : M/s LARSEN & TUBRO REALTY LTD JOB LOACTION : KHAIRNE,NAVI MUMBAI.
CONTRACTOR : LARSEN & TOUBRO CONSTRUCTION SUBCONTRACTOR : CLIFFKUMAR ENGINEERING PVT LTD
PROJECT : LARSEN & TOUBRO BUSINESS TOWER PROJECT JOB NO : 17176

Weld Identification : Job No- C7B J1 Welding process : GMAW/FCAW
Material thickness : 20 MM Quality requirements : AWS D1.1/D1.1M:2015

WELD LOCATION AND IDENTIFICATION SKETCH

Technique SWSI
Source Ir 192
Film to source 20"
Exposure time 8min
Screens 0.1- 0.2 MM
Film type Kodak AA400

(Describe length, width, and thickness of all joints radiographed)

SR NO	Date	Weld Identification	Interpretation		Repairs		Remarks
			Accept	Reject	Accept	Reject	
1	8/6/18	Job-C7B-J1	Yes				Accepted using 6MM

NSD-No significant defects,LF-Lack of Fusan ,T-Tungsten Indusion,IOP-lack of penetration ,BT-Bum Tnrough, SB-Suck Back, Ep-Excess Penetration,UC-Under Cut,UF-Under Flush,PO-porosity.

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared and tested in conformance with the requirements of AWS D1.1/D1.1M, (2015) Structural Welding Code Steel.

INSPECTED/TESTED BY	REVIEWED BY	REVIEWED BY
Name: Bipul Shah	Name: R. PRAKASH	Name: Manoj Nagle
SIGN:	Sign:	Sign:
Test Date: 8/6/18	Test Date: 08/06/18	Test Date:

Smart Technocrats & Consultancy Services (I) Pvt Ltd Larsen & Toubro Construction Cliffkumar Engg Pvt Ltd

4.7 Blasting

Grit blasting shall be used to remove rust, mil scales, paint, and other contaminants and to achieve Sa 2.5 grade. Once blasting is completed, we will check the surface profile with comparator whether it is matching with required grade of Sa 2.5 or not. If the surface profile is not meeting the requirement re-blast, the members until it meets Sa2.5.

5 Erection Of CFT Columns And Steel Beams

5.1 Erection Of Columns

Erection of columns take place by fixing sling ropes to the column. Column is brought to the location and checked for the orientation. Once brought to the place it is placed down at its location. After erection, it is fixed using bolts (temporarily) and then it is locked using tack welding at the edges, once sling ropes are removed then full butt welding of around 20 mm thickness is done throughout the periphery of the column. This welding is done using Metal Inert Gas (MIG) welding machine which increases the productivity and helps in faster completion of the process. The verticality of the columns is regularly checked using advance survey tools such as total station.

5.2 Erection Of Beams

Beam shall be placed on the temporary supports by keeping a gap of at least 10mm at both the ends. At least 50 % bolts shall be fixed at both the ends by providing end cleats to get stability. Alignment shall be completed using water level tube at the two ends. Bolts shall be tightened properly. Post tightening of bolts, welding activity will be started. Welding is done using SMAW method of welding.

Insert plates and anchor plates with bolts are used for the connection of beams with shear wall. Insert plates are fixed in the wall prior to concreting whereas anchor plates are fixed post concreting using anchor bolts.

The total quantity of structural steel used for CFT columns and beams in the project is 4500 Metric Tons.

6 Concreting Of CFT Columns

Concreting of CFT columns is done using a high-grade concrete, at our project concrete of M50 grade was used. This concreting was done using tremie method of concreting. The concrete brought to site was a Self-Compacting Concrete (SSC) hence it saved the additional process of vibrating of concrete. Vent holes were provided in columns so that heat of concrete will be released from the concrete.

7 Synergy Using Metal Deck Slab

0.9 mm to 1.2 mm thick metal sheet used as decking material for tower area. It helps in considerably less thickness of slab and helps in saving concrete quantity. Metal deck is fixed over beams using metal stud. The advantage of metal deck is that no back propping is required which helps in clean construction and other finishing activities can be started without any delay.

8 Fireproofing

In a steel building, fireproofing is an important parameter. It is important to provide a fireproofing compound on all the steel members i.e. columns and beams. Fireproofing was done using Intumescent paint on columns and vermiculite on beams. Both intumescent and vermiculite have a 2 hours fire rating.

9 Manpower Analysis

It is seen that manpower required for construction of steel building is comparatively less than that required for conventional construction as most of the works done in steel building is mechanized.

As per the analysis don at our project, for the area of 3300 sqmt floor plate excluding shear wall; the following manpower is saved. Below table is considered using normal productivity of workers on site:

Sr. No.	Activity	Manpower required for PT slab – slab cycle 21 days	Manpower required for CFT and metal deck slab – slab cycle 13 days
1.	Column carpentry work	31 Carpenters/day – for 4 days	0
2.	Slab and beam carpentry work	95 Carpenters/day – for 7 days	25 Fitters/day for decking – for 3 days
3	Column reinforcement fixing	23 Fitters/day – for 4 days	0
4.	Slab reinforcement fixing	40 Fitters/day – for 4 days	30 Fitters/day – for 3 days
5.	Welders at Factory	0	32 Welders/day – for 6 days
6.	Welders at site	0	60 Welders/day – for 6 days
	TOTAL	**1041**	**717**

As per the above table there was a saving of 324 Man-days/ slab using CFT technology, which is a huge benefit in terms of cost also saving in time as most of the work is done using machine.

Advantages

The following are the advantages seen using CFT technology:

- Faster construction
- Increase in carpet area
- Erection of 2 floors (8.4 Mts) high column in one go
- No shuttering and reinforcement required, thus reducing manpower dependency
- Prefabricated beams with service cutouts can be brought to site
- Mechanized construction leading to reduced labor requirement.

Conclusion

The Successful Completion of Structure with Avg. 13 days slab cycle using CFT Technology at L&T Business Tower Project is a Live Example concludes the fact that use of CFT structure is suitable for high rise commercial building construction and it is expected that in future the demand of CFT will suitably increase and will be used in construction for saving time and high quality. The Move towards Construction mechanization can be greatly achieved by CFT Structures & dependency on skilled labors can drastically come down.

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