ASSESSING THE PERFORMANCE OF CONCRETE FILLED STEEL TUBE COLUMN(CFST) AND PROFILED STEEL DECK SLAB ALONG WITH NANOTECH MATERIAL(GO) IN TERMS OF COST , TIME & SPACE

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Abstract - *This paper delves into the benefits of CFST (Concrete Filled Steel Tube) columns and profiled steel deck composite roofs, enhanced with graphene oxide nanotechnology, with a focus on space, cost, and time efficiencies. It conducts a comparative analysis of CFST column performance with graphene oxide against RCC (Reinforced Concrete Cement) columns and compares profiled steel deck slabs with RCC slabs. Through multi-case studies and empirical investigation, the study emphasizes the advantages of composite construction in terms of speed, performance, and value. Cost estimates derived from supplier interviews and real-time market values are analyzed alongside conventional RCC structures using Spreadsheet for cost comparison and E-TAB for performance analysis, while Primavera software is used for time analysis. The findings reveal significant reductions in construction timelines and costs attributed to decreased weight and elimination of false works. Specifically, a G+17 commercial building project demonstrates a 30.4% cost reduction and a 19.4% time efficiency improvement with composite construction over traditional RCC. The replacement of RCC columns with CFST columns results in the elimination of three columns, maintaining balanced shear stress and bending moments and leading to a 76% reduction in column area, thus achieving significant spatial savings. Furthermore, the incorporation of graphene oxide into concrete enhances strength, reduces permeability, increases resistance to corrosion and cracking, and accelerates curing. This amalgamation of cost efficiency, improved construction speed, and optimized structural performance underscores the advantages of composite construction for commercial building projects.*

***Key Words*: CFST column, profiled steel deck slab, graphene oxide(GO), nanotech material, cost, time, space**

1.INTRODUCTION

Structural engineering practices in India have historically favored masonry construction, but modern trends lean towards R.C.C or Steel framed structures for multi-story buildings. The recent surge in interest towards composite structures, spurred by past building failures during seismic events, underscores the industry's quest for safer alternatives. Composite or hybrid materials have emerged as promising solutions, offering enhanced performance without significant changes to manufacturing or construction methods.

Despite their clear benefits, the adoption of steel-concrete-composite structures among Indian consulting engineers has been cautious due to perceived complexities in analysis and design. However, existing literature suggests that well-designed composite systems can deliver cost-effective, time-efficient, and space-efficient structural solutions, boasting rapid erection, durability, and superior seismic performance.

Given the evolving landscape and the absence of updated design codes, there's a pressing need to explore composite analysis and design for multi-story buildings, particularly in the Indian context. Our study focuses on interpreting the advantages of replacing traditional R.C.C structures with Concrete Filled Steel Tube (CFST) columns, steel beams, and profiled steel deck slabs in a G+17 Storey building. We assess structural stability, cost, space, and time efficiency while also exploring the benefits of incorporating Graphene oxide, a nanotech material. Through this research, we aim to provide valuable insights into the advantages of composite construction, particularly CFST columns and profiled steel deck slabs, augmented with graphene oxide, within the Indian construction industry.

2. OBJECTIVE

The primary objectives of this research study are:

Analysis of CFST Column: Examine the cost, space, and time factors associated with Concrete-Filled Steel Tube (CFST) columns to assess their economic feasibility, spatial efficiency, and construction speed.

Spatial Comparison with RCC Column: Conduct a spatial comparison between RCC and CFST columns to determine their relative physical dimensions and spatial efficiency.

Study of Nanotech Materials for CFST Column: Investigate various nanotechnology materials to identify the most cost-effective and time-efficient option for enhancing CFST column performance.

Analysis of Profiled Steel Deck Composite Roof: Evaluate the cost and time implications of using Profiled Steel Deck Composite roofs in construction projects.

Performance Analysis of CFST Column and Composite Roof: Analyze the overall performance of CFST columns and composite roofs, focusing on cost, time efficiency, and the impact of graphene oxide as a nanotech material on their performance in real-world applications.

3. METHODOLOGY

This study entails a two-fold approach. Firstly, a comprehensive literature review will be conducted to explore composite column and roof systems and nanotech material study emphasizing their benefits in construction projects. Following this, an empirical investigation employing a multi-case study approach will analyze the study objectives .Cost estimates derived from supplier interviews will be utilized, and the additional costs of composite column and roof systems will be compared to conventional RCC elements using E-tab, Spreadsheet and Primavera software.

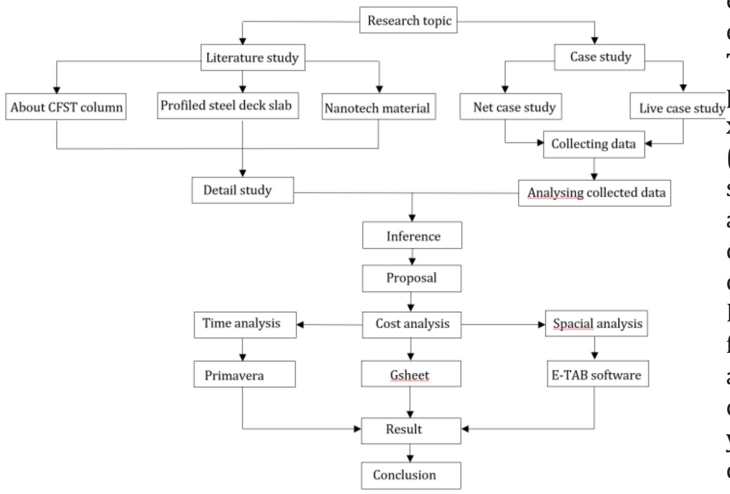

Figure -1: Methodology flowchart

4. SCOPE AND LIMITATION

This study delve into a comprehensive analysis of various factors including material costs, labor expenses, and the time required for construction. Specifically, we compare these aspects between two construction methods: conventional construction, which relies on Reinforced Concrete Cement (RCC) for structural purposes, and composite construction, which integrates concrete with ,steel. Our focus narrows down to the incorporation of graphene oxide within composite structures. By scrutinizing these elements, we aim to shed light on the comparative advantages and potential efficiencies offered by composite construction methods, particularly those utilizing graphene oxide.

5. LITERATURE REVIEW

The Steel option outperforms R.C.C, but for high-rise buildings, the Composite option is best. It reduces dead weight by 30-32%, with significant reductions in steel member sizes. **(D. R. Panchal and P. M. Marathe,2011).** Including 0.04% graphene oxide (GO) in the cement paste improved compressive strength by up to 15.1% compared to plain cement paste. Additionally, incorporating 0.03% GO by weight of cement (bwoc) in ordinary Portland cement (OPC) paste increased both compressive and tensile strength by over 40% after 28 days of curing. GO functions as a catalyst, accelerating cement hydration without altering the oxygenated functional groups. **(S.C. Devi,2020)**

6. CASE STUDY

6.1. CFST COLUMN

In a construction project integrating CFST (Concrete Filled Steel Tube) technology across 14 acres, boasting a built-up area of 5.6 lakh sq.ft, the endeavor spanned 7 years and incurred a total cost of ₹450 Cr. (450 Crores). This structure, encompassing 5 floors and 3 basements, strategically employed CFST columns in the aisle area on a partial basis. These CFST columns, towering approximately 80ft height, present a distinct contrast to RCC columns, measuring 0.8m x 0.8m (0.64 sq.m) for 64ft before shrinking to 0.5m x 0.5m (0.36 sq.m) at the top 16ft height. This reduction in column size with CFST results in a notable 43.75% saving in spatial area. Additionally, a meticulous material quantity analysis conducted with the assistance of RCC structural and steel consultants revealed significant cost disparities between RCC and CFST. These differences include a 52.2% lower cost for cement bags, a 52.4% decrease in fine aggregate cost, and a 52.5% reduction in coarse aggregate cost. However, CFST columns require 38.3% more steel than RCC counterparts, yet the return on value of steel is higher in CFST construction.

6.2.PROFILED STEEL DECK

A commercial complex project in Madurai, featuring a G+1 structure, spans a site area of 2480 sq.ft with a built-up area of 2290 sq.ft, designed for commercial usage over two floors of 1100 sq.ft each. The construction involves 20 I-section column girders measuring 800mm x 400mm, which are erected in just 2 days using a single crane. The foundation comprises pile foundations reaching a depth of 9 feet, utilizing a 16mm main rod and 8-inch circular stirrup gap, with a foundation radius of 1 foot 6 inches. Site clearance is expected to take 1 day, and foundation work up to plinth level is scheduled for 2.5 weeks.For the profiled steel deck slab construction, 39 JSW sheets are used, with a contracted work cost of Rs. 1500 per sq.ft. The construction employs 10mm steel rods, with 3 days dedicated to tukkin sheet and reinforcement work, followed by 1 day for concreting. The total cost, including formwork at 1.5%, is Rs. 2,76,660.786.

An analysis comparing this method to conventional RCC slab construction reveals significant cost savings and time efficiency. The use of Renocon blocks further reduces material quantity by 30-40%, showcasing a 24.75% cost difference in favor of the steel deck slab and a 32% reduction in construction time compared to RCC slabs.

Table-1: Profiled deck slab and RCC slab material quantity comparison

Material	Profiled steel deck slab	RCC slab
Form work	1.5%	3%
Cement	79bags	119bags
Steel	685 kg	980kg
Fine aggregate	198cu.ft	297 cu.ft
Course aggregate	297 cu.ft	446 cu.ft
Steel deck sheet	39no.s	

In a G+5 structured commercial project, approximately 400 sheets of JSW brand steel are utilized, with a work contract priced at Rs. 1450 per sq.ft. Construction incorporates 12mm and 16mm steel rods. The pile foundation, reaching depths of 25 feet due to soil sedimentations, faced delays due to financial settlement issues, extending the foundation work duration to 2 months. The buildup area spans 15,028 sq.ft, featuring a commercial typology across ground plus three floors. The steel roof design aims for slim girders spanning over 30 ft, achieved through a diagonal grid connection. Façade columns measure 800mm x 600mm, composed of welded steel plates, with beams prefabricated or constructed on-site in two pieces. Interlocking blocks expedite construction and reduce mortar costs. Column erection, facilitated by two equipment, takes around 20 days. During roof tukking, approximately 12 laborers are involved, taking 11 days, while reinforcement and concreting require 12 days and 1 day, respectively. Each floor's roof work is completed in 25 days. For the profiled steel deck slab, the total cost, including 1.5% formwork, amounts to Rs. 5,87,470.83, while conventional RCC slab replacement costs Rs. 9,06,821.27, including 3% formwork. Material quantity savings of 30-40% are achieved, with a notable 35.21% cost difference favoring the steel deck slab, which also saves 37.5% of construction time compared to conventional methods.

Table- 2: Material quantity comparison G+5 storey building

Material	Profiled steel deck slab	RCC slab
Form work	1.5%	3%
Cement	258 bags	386 bags
Steel	685 kg	980kg
Fine aggregate	644 cu.ft	966 cu.ft
Course aggregate	966 cu.ft	1149 cu.ft
Steel deck sheet	400 no.s	

Based on the case study analysis and data collection during case study and discussion with the field expertise the drawbacks of profiled steel deck slabs are notable. Without proper painting, there's a risk of corrosion over time, especially if the paint quality is poor. Moreover, if water sealing isn't done adequately, it can lead to leakage problems, compromising the integrity of the metal sheets. Installing tile flooring can also pose issues with vibrations, prompting a preference for concrete polishing instead. Fortunately, these challenges can be addressed with graphene oxide, offering a solution to counter the disadvantages associated with profiled steel deck slabs. Despite these concerns, it's worth noting that profiled steel deck slabs exhibit exceptional durability and resilience, capable of resisting rust for 60 to 75 years when maintained properly.

6.3. GRAPHENE OXIDE

In the case study of a residential building located in Chitlapakam, Chennai, comprising a stilt plus three floors structure, with a site area of 2762 sq.ft and a build-up area of 7300 sq.ft, innovative use of graphene oxide (GO) in concrete has been employed. Concrete elements, utilizing M25 grade concrete, have been enhanced by adding 0.01mg to 0.06mg of GO per bag of cement, resulting in stronger compressive strength and reduced curing periods. This addition has led to a reduction in material quantity requirements and accelerated concrete setting by 50%, thereby saving construction time on-site. Specifically, in the stilt plus three project, the reduction in curing periods and the introduction of parallel activities have collectively saved 37 days from the total construction period of 309 days. Although initial estimations suggested a potential 40% cost reduction, a realistic assessment indicates a more modest yet significant 9-12% reduction, equivalent to approximately Rs. 12-16 lakh cost saving in this project. Each bag of cement in the concrete mixture is supplemented with 0.04mg of GO, while 0.01mg is used for plastering walls. This case study underscores GO's potential to deliver substantial cost savings, with the percentage increasing with the number of storeys in a building, reaching up to 40% in certain scenarios.

7. ANALYSIS

7.1.SPATIAL ANALYSIS

The analysis focuses on a commercial office building (G+17) situated on a 10-acre plot of land, boasting a total built-up area of 2.4 million square feet . Specifically, Tower A and Tower B, comprising a combined area of 82,500 square feet (32,500 sq. ft for Tower A and 50,000 sq. ft for Tower B), are selected for spatial analysis using E-TAB software, cost analysis utilizing spreadsheet, and time analysis through Primavera. The building's construction primarily utilizes Reinforced Concrete (RCC) structural elements, with a glass facade. Proposed modifications include replacing RCC columns with Concrete-Filled Steel Tube (CFST) columns and RCC slabs with profiled steel deck slabs, aimed at enhancing effectiveness. Additionally, the analysis explores the introduction of graphene oxide into the structure. The existing building features two types of RCC columns: square columns measuring 1.5 meters by 1.5 meters and elliptical columns with a radius of 0.3 meters, totaling 53 columns.

Model info for RCC column and RCC slab:

Considered according to equilateral method

3-D model is being prepared for the frame static analysis of the building in ETABS

The basic parameters considered for the design

Slab depth : 300 mm thick

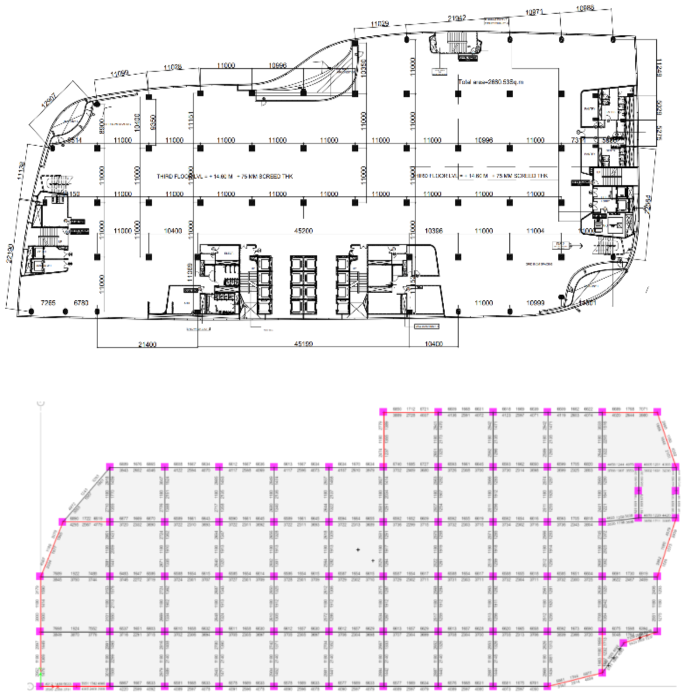

Figure-2: (Existing plan and ETAB generated RCC column and slab plan)

Live load in office area : 5.0 kN/sq m

Live load in passage area : 5.0 kN/sqm

Live load in urinals : 2 kN/sq m

Floor finish load : 1.5 kN/ sq m

Seisemic load- 2.5KN/sq m

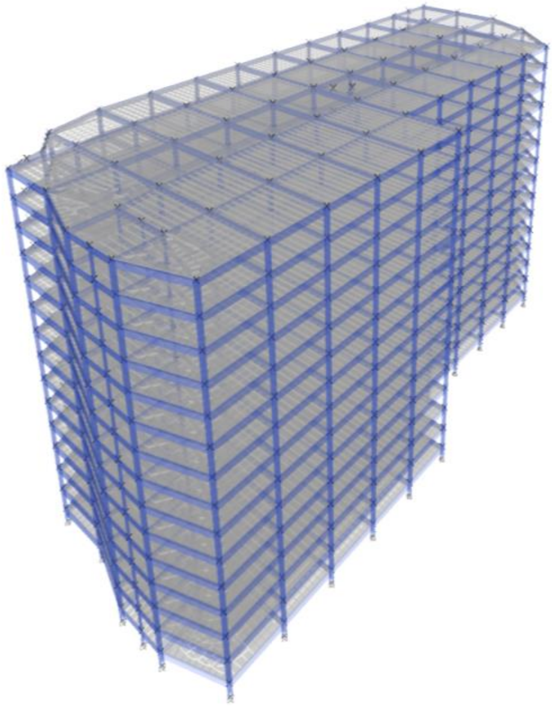

Figure-3:(ETAB generated model)

Model has passed the structural requirement with the

Column size-1.5m x1.5m

Beam size- 0.3m x 0.6m

Slab thickness – 300mm

Model info for CFST column and Profiled steel deck slab:

Considered according to equilateral method

3-D model is being prepared for the frame static analysis of the building in ETABS

The basic parameters considered for the design

Slab depth : 150 mm thick

Live load in office area : 4.0 kN/sq m

Live load in passage area : 4.0 kN/sqm

Live load in urinals : 1.75 kN/sq m

Floor finish load : 1.0 kN/ sq m

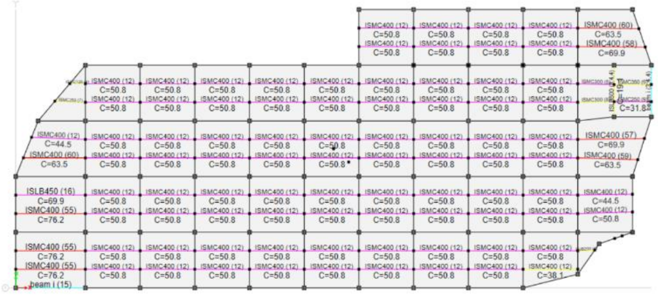

Figure- 4:(ETAB generated CFST column and Profiled deck slab plan)

Model has passed the structural requirement with the

column size-0.75m x0.75m

Beam size- 0.3m x 0.14m

Slab thickness – 150mm

The Spatial comparison between the RCC (Reinforced Concrete) column and the CFST (Concrete-Filled Steel Tube) column reveals significant differences in their characteristics and efficiency. For the RCC column, considering a total floor area of 6670.46 square meters and a column area of 130.5 square meters, with a size of 1.5 meters by 1.5 meters, the clear floor area is calculated as 6540 square meters. On the other hand, the CFST column, with the same total floor area, has a smaller column area of 32.625 square meters, corresponding to a column size of 0.75 meters by 0.75 meters. Consequently, the clear floor area increases to 6637.3 square meters. The comparison indicates that the replacement of composite with RCC columns results in the reduction of three columns, achieving a balance in shear stress and bending moment. Additionally, the column area saved amounts to 76%, indicating a substantial improvement in structural efficiency and material utilization.

7.2.COST ANALYSIS

7.2.1.COLUMN

A comparative analysis between traditional Reinforced Concrete (RCC) columns and Concrete-Filled Steel Tube (CFST) columns reveals significant differences in cost efficiency and structural capabilities. The construction cost for RCC columns totals Rs. 52,94,74,657.2. This includes using square columns of 1.5m x 1.5m and elliptical columns with a 0.3m radius, made with M40 grade concrete for structural stability. In contrast, CFST columns have a much lower construction cost of Rs. 28,50,09,298.72. This reduction is due to more efficient column sizes: 0.75m x 0.75m for square columns and elliptical columns with a 0.15m radius. The CFST columns use M30 grade concrete enhanced with graphene oxide (GO), improving structural performance.

7.2.2.BEAM

Comparing traditional Reinforced Concrete (RCC) beams with Composite Steel beams shows notable differences in cost and structural efficiency. RCC beams cost Rs. 17,65,76,083.8 in total. These beams are 0.3m x 0.6m in size and use M40 grade concrete to ensure stability, following industry standards. On the other hand, Composite Steel beams cost less, at Rs. 14,60,86,292.9. This cost reduction comes from using more efficient steel beam sizes of 0.35m x 0.14m. These beams adhere to strict standards, including for designing composite beams and slabs and Composite Steel and Concrete Structures.

7.2.3.ROOF

Comparing conventional Reinforced Concrete (RCC) slabs with Profiled Steel Deck slabs reveals significant differences in both cost and structural efficiency. The total cost for RCC slabs amounts to Rs. 85,65,26,079, while Profiled Steel Deck slabs are significantly more economical, costing Rs. 55,10,42,643.1. Structurally, RCC slabs have a substantial thickness of 300mm, utilizing M40 grade concrete to meet industry standards for stability and load-bearing capacity. In contrast, Profiled Steel Deck slabs are considerably thinner at 150mm. Despite using M30 grade concrete, which is generally of lower strength compared to M40, the incorporation of graphene oxide (GO) enhances the structural integrity of these slabs. Graphene oxide improves the concrete's strength, reduces permeability, and increases resistance to cracking and corrosion. This enhancement allows Profiled Steel Deck slabs to achieve superior performance with a reduced thickness, leading to better material efficiency and cost-effectiveness. This comparison highlights the financial advantages and improved structural efficiency of Profiled Steel Deck slabs, making them a favorable alternative for modern construction projects aiming for optimal performance and economy.

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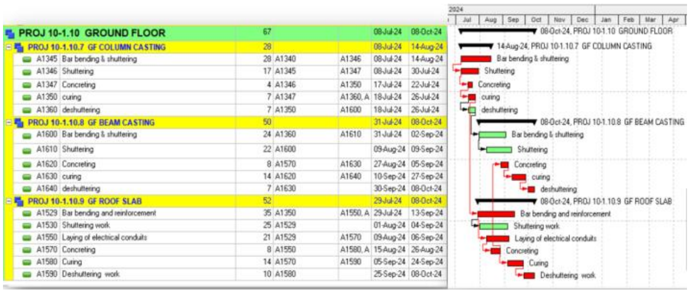
Table-3: Material cost and quantity comparison

Material cost difference				
Material	Unit	RCC column& slab (M40)	Composite column &deck slab (M30)+GO	% of difference
Cement	Rs	792247219	281581983	64.5%
Steel	Rs	58850519	48033842.2	18.4%
Fine aggregate	Rs	1898692.3	943705.68	50.4%
Coarse aggregate	Rs	3529649.2	1227828.41	65.3%
Profiled steel deck	Rs	-	7772659.81	
Graphene oxide	Rs		26100	
Material quantity difference				
Material	Unit	RCC(M40)	Composite (M30)	% of difference
Cement	bag	18,424	6,548	**64.5%**
Steel	kg	7,84,673.5	7,38,523	**5.9%**
Fine aggregate	Cu.m	30,624	10,216	**66.7%**
Coarse aggregate	Cu.m	18,439.85	6,645	**64.7%**
Profiled steel deck	No.s	-	6375	
Graphene oxide	Mg/ bag		261.93	

7.3.TIME ANALYSIS

Interpreting the project for analysis, project operates on a schedule of 6 working days per week, with Sundays designated as holidays. Each working day is presumed to consist of 8 hours of labor. The efficiency of labor work is calculated based on established standards and incorporated into this analysis. Since it is a large scale project in order to speed up the construction time ,activities were parallelly assigned

Table-4:RCC column and slab time line schedule



PROJ 10-1.10 GROUND FLOOR		67			08-Jul-24	08-Oct-24
PROJ 10-1.10.7 GF COLUMN CASTING		28			08-Jul-24	14-Aug-24
A1345	Bar bending & shuttering	28	A1340	A1346	08-Jul-24	14-Aug-24
A1346	Shuttering	17	A1345	A1347	08-Jul-24	30-Jul-24
A1347	Concreting	4	A1346	A1350	17-Jul-24	22-Jul-24
A1350	curing	7	A1347	A1360, A	18-Jul-24	26-Jul-24
A1360	deshuttering	7	A1350	A1600	18-Jul-24	26-Jul-24
PROJ 10-1.10.8 GF BEAM CASTING		50			31-Jul-24	08-Oct-24
A1600	Bar bending & shuttering	24	A1360	A1610	31-Jul-24	02-Sep-24
A1610	Shuttering	22	A1600		09-Aug-24	09-Sep-24
A1620	Concreting	8	A1570	A1630	27-Aug-24	05-Sep-24
A1630	curing	14	A1620	A1640	10-Sep-24	27-Sep-24
A1640	deshuttering	7	A1630		30-Sep-24	08-Oct-24
PROJ 10-1.10.9 GF ROOF SLAB		52			29-Jul-24	08-Oct-24
A1529	Bar bending and reinforcement	35	A1350	A1550, A	29-Jul-24	13-Sep-24
A1530	Shuttering work	25	A1529		01-Aug-24	04-Sep-24
A1550	Laying of electrical conduits	21	A1529	A1570	09-Aug-24	06-Sep-24
A1570	Concreting	8	A1550	A1580, A	15-Aug-24	26-Aug-24
A1580	Curing	14	A1570	A1590	05-Sep-24	24-Sep-24
A1590	Deshuttering work	10	A1580		25-Sep-24	08-Oct-24

Each floor is constructed at a consistent pace, requiring 67 days to complete. With a total of 17 floors, the cumulative time for construction is calculated as 17 multiplied by 67, resulting in 1139 days. Additionally, the construction of the foundation to the third basement level takes 193 days. Hence, the total number of construction days for the RCC structure amounts to 1132 days, equivalent to approximately 3.1 years.

Table-5: CFST column and Profiled deck slab construction time line schedule

PROJ 10-2.10 GROUND FLOOR		49			18-Jun-24	23-Aug-24
PROJ 10-2.10.7 GF COLUMN CASTING		8			18-Jun-24	27-Jun-24
A1345	Steel profile placement	6	A1340	A1346, A	18-Jun-24	25-Jun-24
A1346	Shuttering	0	A1345		18-Jun-24	18-Jun-24
A1347	Concreting	7	A1345	A1350	19-Jun-24	27-Jun-24
A1350	curing	3	A1347	A1360, A	20-Jun-24	24-Jun-24
A1360	deshuttering	0	A1350		20-Jun-24	20-Jun-24
PROJ 10-2.10.8 GF BEAM CASTING		27			25-Jun-24	01-Aug-24
A1600	Steel section placement and connecting	20	A1350	A1610, A	25-Jun-24	22-Jul-24
A1610	Shuttering	0	A1600		25-Jun-24	25-Jun-24
A1620	Concreting	0	A1570	A1630	30-Jul-24	30-Jul-24
A1630	curing	0	A1620	A1640	01-Aug-24	01-Aug-24
A1640	deshuttering	0	A1630		01-Aug-24	01-Aug-24
PROJ 10-2.10.9 GF ROOF SLAB		24			23-Jul-24	23-Aug-24
A1529	Scaffolding work	14	A1600	A1530	23-Jul-24	09-Aug-24
A1530	Tukking sheet	22	A1529	A1550	24-Jul-24	22-Aug-24
A1550	Laying of electrical conduits	20	A1530	A1570	26-Jul-24	22-Aug-24
A1570	Concreting	4	A1550	A1580, A	30-Jul-24	02-Aug-24
A1580	Curing	7	A1570	A1590	08-Aug-24	16-Aug-24
A1590	Deshuttering work	5	A1580		19-Aug-24	23-Aug-24

For composite structure-each floor is constructed within a timeframe of 47 days. With a total of 17 floors, the cumulative time required for construction is determined by multiplying 17 by 47, resulting in 799 days. Additionally, the construction of the foundation up to the third basement level entails a period of 175 days. Therefore, the total number of construction days for the RCC structure is calculated as 799 days for floor construction plus 175 days for foundation to basement 3 construction, yielding a total of 974 days. This timeframe equates to approximately 2.5 years for the completion of the RCC structure.

8.0.RESULT

Table- 6: RCC Construction and CFST column & profiled steel deck slab (composite construction) comparison

Parameters	**RCC construction**	**Composite construction**
Column size	1.5mx1.5m	0.75mx0.75m
Beam size	0.35mx0.6m	0.35mx0.14m
Slab thickness	300mm	150mm

Cost of construction	168cr	117cr
Time of construction	3.1yr	2.5yr

After conducting a comprehensive analysis encompassing spatial, cost, and time considerations for the Commercial building project, it has been revealed that there is a significant cost difference of 30.4% between traditional Reinforced Concrete (RCC) construction and the proposed composite construction replacement in G+17 building . Additionally, a time difference of 19.4% has been identified, indicating a notable improvement in construction efficiency with the composite construction approach with the addition of graphene oxide inclusion . Additionally replacing the RCC columns with CFST columns resulted in the elimination of three columns while maintaining balanced shear stress and bending moments. This replacement also led to a 76% reduction in column area in G+17 commercial building which helps in spatial area saving.

9.0.CONCLUSIONS

The comprehensive analysis of the commercial building project highlights the substantial benefits of adopting composite construction over traditional Reinforced Concrete (RCC) construction. The proposed composite method offers notable cost savings and enhances construction efficiency, allowing for quicker project completion. Replacing RCC columns with Concrete-Filled Steel Tube (CFST) columns optimizes the building's structural performance, ensuring balanced shear stress and bending moments, and significantly reducing the column area. This reduction results in more usable floor space within the building. Using profiled steel deck slabs provides rapid installation due to their lightweight and prefabricated nature, reducing construction time and labour costs. They act as permanent formwork, eliminate the need for temporary supports, and enhance load-bearing capacity, allowing for longer spans with fewer columns. This leads to cost savings on materials and increased design flexibility. Additionally, they are durable, often coated with corrosion-resistant graphene oxide paint, and contribute to sustainable building practices through recyclable materials. Incorporating graphene oxide into concrete mixtures enhances mechanical and durability characteristics. It improves strength, reduces permeability, and increases resistance to corrosion and cracking. Graphene oxide can also accelerate the curing process, offering time and energy savings. The combination of cost efficiency, improved construction speed, and optimized structural performance underscores the advantages of composite construction for commercial building projects. This method facilitates better resource utilization and offers enhanced design flexibility, making it a highly beneficial alternative for modern construction needs.

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