Structural Analysis of CFST and DS CFST Using ANSYS Workbench

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Abstract— *Concrete-Filled Steel Tubes (CFSTs) have emerged as efficient structural members in modern construction due to their superior strength, stiffness, and ductility arising from the composite interaction between a steel tube and infilled concrete. However, the depletion of natural river sand, a primary component of conventional concrete, has raised sustainability concerns and prompted the search for alternative fine aggregates. In this context, dune sand, abundantly available in desert regions, offers potential as a sustainable replacement material. This thesis presents a comparative study of the structural performance of conventional CFST and Dune Sand Concrete-Filled Steel Tubes (DS CFST) through finite element analysis (FEA) conducted in ANSYS Workbench.*

Both CFST and DS CFST models were developed with identical geometry (1000 mm height, 150 mm diameter, 5 mm steel thickness), material definitions, meshing strategies, and boundary conditions to ensure direct comparability. Static structural analyses evaluated maximum deformation and equivalent elastic strain, while eigenvalue buckling analyses assessed critical load multipliers and mode shapes. Results indicated that DS CFST exhibited nearly identical deformation (9.37×10^{-9} m vs. 9.40×10^{-9} m for CFST) and slightly lower strain (2.63×10^{-8} m/m vs. 2.84×10^{-8} m/m). DS CFST showed a marginally higher buckling load multiplier (4.05×10^{5}), suggesting improved global stability.

The findings confirm that dune sand concrete can replace conventional concrete in CFSTs without compromising performance, while contributing to sustainable construction practices by reducing reliance on river sand. The study provides novel numerical evidence supporting DS CFST as a viable structural solution, particularly suited for sand-rich and desert regions. Limitations include the exclusive reliance on simulations and single geometry and future research should incorporate experimental validation, varied loading conditions, and extended geometrical configurations.

Keywords—Concrete-Filled Steel Tubes, Dune Sand, Finite Element Analysis, ANSYS, Buckling, Sustainable Construction

I. INTRODUCTION

A. Background of Composite Columns in Structural Engineering

The field of structural engineering has experienced a tremendous transformation throughout the past century whereby much consideration has been given to the creation of systems that are not only structurally effective, but also sustainable, cost-effective, and responsive to the needs of the time. The invention of composite structural members is one of the greatest innovations in this area. The best example of such innovation is composite columns, which is formed by gluing two or more materials to act as one. They are usually built in steel and concrete where the merits of both materials are incorporated together. The steel offers tensile property and ductile properties, whereas the concrete offers compressive strength and rigidity. These materials compose a synergistic performance that is better than that of either material when used separately (Han, 2016; Johansson and Gylltoft, 2002).

Composite columns, especially Concrete-Filled Steel Tubes (CFST) have become popular because of their enhanced structural performance over the traditional reinforced concrete (RC) or pure steel columns. In CFSTs, concrete is contained in a steel tube effectively constraining it and preventing cracking and crushing to occur too soon. This isolation effect not only increases the axial and flexural load bearing capacity of the system, but also decreases local buckling of the steel tube. Therefore, CFSTs bring together compressive strength of concrete and tensile resistance of steel in one and highly efficient load bearing member (Shanmugam and Lakshmi, 2001).

These structural members are used extensively in the high-rise buildings, bridges, towers, and seismic-resistant structures. Indicatively, tallest skyscrapers in the world such as some in China, Japan and Middle East have intensively utilized CFST columns due to their good strength to weight ratio, resistance to fire and seismic behavior (Han et al., 2014). Comparing CFST with RC or steel columns, CFST itself can withstand the same weight with a smaller cross-section, allowing architects and engineers to make slimmer columns and use all of the available floor space, which is the most important consideration in the construction of high-rise buildings. The efficiency of composite columns is another benefit of the columns [1].

In contrast to reinforced concrete columns, CFSTs do not need the use of formwork nor the reinforcing to be installed, thus cutting down on construction time and labor expense. The steel tube serves as a permanent formwork and reinforcement, and this reduces any construction errors and improves quality control (Ellobody and Young, 2006). Such a twofold ability has seen CFSTs used as a viable solution to high-speed urban development initiatives.

CFSTs are also good at dynamic and extreme loading including impact, blast and seismic loads. It has been found that the combination of steel and concrete gives very good energy absorption capacity, a feature that is vital in the earthquake-prone areas (Varma et al., 2005). It increases the fire resistance since the concrete slows down the heating and degrading process of the steel tube, providing superior resistance to the fire hazards when compared to the plain sections of steel [2].

Composite column integration especially CFSTs in modern infrastructure is a significant structural engineering innovation. Their high-mechanical performance, cost-effectiveness, and sustainability to the principles of sustainable design have won their acceptance in developed and developing nations.

B. Role of CFST in Modern Infrastructure

Urbanization, high construction pressure, and sustainable and resilient buildings are the main factors that have resulted in the large-scale use of CFSTs in modern-day infrastructure. The structures members used in vertical cities should be able to withstand high axial loads in a small area, and these structural members need to be serviceable and safe. The CFSTs have come out as an ideal solution to such challenges. CFST columns have a number of advantages in the construction of high-rise buildings. First, they have lower slenderness ratio than conventional reinforced concrete columns, which increases stability. Second, CFSTs have high strength-to-weight ratio, which allows taller structures without unnecessarily raising the foundation load (Han et al., 2014) [3].

Thirdly, CFST members are less cross-sectional and hence, aesthetic which sustains the current trend of modern architecture where space use is significant. CFSTs, too, are commonly applied in bridge piers and pylons. Columns in bridge engineering would be under heavy axial loads, bending forces and shear forces and in extreme environments. When filled with high-performance concrete, CFTs offer high durability and resistance to corrosion, making them last longer than the key infrastructure. As an example, the Lupu Bridge in Shanghai and a few cable-stayed bridges in Japan make use of CFST piers in order to guarantee the performance of the bridges over time due to dynamic traffic and wind forces (Shams & Saadeghvaziri, 1999) [4].

C. Importance of Finite Element Analysis (FEA) for Predicting Performance

Finite Element Analysis (FEA) has emerged as a masterpiece in the field of structural engineering studies and application. It is a potent computational tool that gives engineers an opportunity to forecast the behavior of complex structures in a mechanical context of numerous loading and boundary conditions. In contrast to the traditional analytical solutions, which tend to simplify their assumptions, FEA enables a detailed modeling of the nonlinearity of the material, geometric anomalies, as well as interaction of loads, which leads to results that are very close to the actual performance (Cook et al., 2007).

Experimental testing is, by no doubt, the most precise way to test performance in the case of Concrete-Filled Steel Tubes (CFSTs) and Dune Sand Concrete-Filled Steel Tubes (DS CFSTs).

Yet, the large scale experiments have been not only costly but time consuming, and also, restricted. Indicatively, the economic cost of testing a complete group of columns with various axial forces, eccentricities, and boundary conditions is quite expensive in terms of financial investment, manpower, and laboratory facilities (Han, 2016). FEA represents an effective alternative as it allows the researcher to model various conditions at a very low cost and time, which makes it an inseparable component of contemporary structural studies

D. Research Objectives

UThis thesis seeks to contribute to the growing body of knowledge on sustainable composite structures by focusing on the comparative structural behavior of CFSTs and DS CFSTs using Finite

Element Analysis in ANSYS Workbench. The research is guided by the following objectives:

1. To model and simulate CFST and DS CFST columns using ANSYS Workbench.

Geometry creation in Design Modeler for both CFST and DS CFST. Definition of material properties for structural steel, conventional concrete, and dune sand concrete. Application of realistic boundary conditions and loading parameters.

2. To evaluate the mechanical performance of CFST and DS CFST columns under static axial loading.

Analysis of stress distribution, deformation, and strain profiles. Identification of critical zones within steel tubes and concrete cores.

3. To determine the buckling behavior of CFST and DS CFST columns.

Conduct eigenvalue buckling analysis to estimate critical load multipliers. Compare global buckling capacities of both systems.

4. To conduct a comparative study between CFST and DS CFST.

Assess differences in deformation, strain, and buckling resistance. Quantify the impact of dune sand concrete on structural performance.

5. To evaluate the feasibility of dune sand concrete as an alternative to natural sand concrete in CFST applications.

Determine whether DS CFST exhibits comparable or improved load-bearing and stability characteristics. Provide insights into the sustainability and practical application of DS CFST in desert or sand-abundant regions.

By addressing these objectives, this thesis aims to establish a scientific basis for using dune sand concrete in high-performance composite structural systems.

II. Literature Review

A. *Research on CFST Behavior under Axial and Lateral Loads*

Concrete-Filled Steel Tubes (CFSTs) have gained massive attention in the field of structural engineering research because of their high load bearing ability, plasticity, and composite behavior. They are created by pouring concrete in hollow steel tubes thus combining the compressive strength of concrete with tensile resistance and confinement of steel in a synergistic manner. A lot of research has been done to learn their structural behavior in various loading conditions especially the axial and lateral loads. This part summarizes the state of the art of CFST performance, determines key influencing parameters, and sheds light on gaps of interests to the existing research.

B. *Use of Alternative Infill Materials in CFSTs*

Concrete-Filled Steel Tubes (CFSTs) traditionally employ conventional concrete made using natural river sand as fine aggregate. However, the growing scarcity of natural sand, coupled with sustainability concerns and rising costs, has encouraged research into alternative infill materials for CFST systems. Such alternatives include quarry dust, fly ash, recycled aggregates, slag, and dune sand. These substitutes aim not only to preserve natural resources but also to improve mechanical or durability properties of the concrete core [5].

Quarry dust, a by-product of stone crushing, has been investigated as a partial or full replacement for natural sand in concrete. Several studies report that quarry dust can enhance the compressive strength of concrete due to its angular particle shape and better interlocking ability (Ilangovana, Mahendran, & Nagamani, 2008). When used in CFSTs, quarry-dust concrete improves confinement effects by enhancing bond strength between the steel tube and concrete core (Muda & Diah, 2013) [6].

C. *Mechanical Performance of Dune Sand Concrete in Civil Works*

Dune sand has been widely investigated for use in general civil engineering applications such as concrete, mortar, and road construction. Its performance depends largely on grading, blending ratio, and mix design.

Properties of Dune Sand

Dune sand particles are generally finer and smoother compared to river sand. Their rounded morphology reduces friction and interlocking, leading to lower compressive and flexural strength in plain concrete (Sabat, Pati, & Nayak, 2015). The fineness modulus of dune sand is typically below 2.0, indicating a higher proportion of fine particles. This can adversely affect workability unless combined with coarser aggregates or chemical admixtures (Al-Harthy et al., 2007).

Compressive and Tensile Strength

Research has shown that replacing natural sand with dune sand up to 30–40% in concrete mixes results in compressive strengths comparable to conventional concrete (Bansal & Kapoor, 2014). Beyond this range, strength tends to decrease due to insufficient particle interlock.

In terms of tensile strength, dune sand concrete generally shows slightly lower splitting tensile strength compared to river-sand concrete. However, the reduction is not critical when the concrete is confined in structural members like CFSTs, where tensile stresses are mainly resisted by the steel tube (Han & Yang, 2003).

Low-rise housing, pavements and non-structural elements in the Middle East countries have provided successful applications of Dune sand concrete (Al-

Harthy et al., 2007). Its application in load bearing structural members is, however, restricted because of strength and durability considerations. The confinement of CFSTs creates a special chance to expand the use of the dune sand concrete to the high-performance structural systems.

D. *Previous Numerical/FEA Approaches for Composite Columns*

Finite Element Analysis (FEA) has become an essential tool for investigating CFSTs. Advanced simulation platforms such as ANSYS, ABAQUS, and LS-DYNA allow researchers to model the nonlinear interaction between steel and concrete.

CFSTs typically model steel as an isotropic hardening elastic-plastic material. More complicated constitutive laws are, however, necessary to represent nonlinear stress-strain behavior, confinement effects, and cracking/crushing effects on concrete (Ellobody and Young, 2006). It is often used with the Concrete Damaged Plasticity (CDP) model of ABAQUS, and with the multilinear models of ANSYS. These models can simulate stiffness degradation, post-peak softening, and cyclic behavior [7].

FEA studies emphasize the importance of correctly modeling the interface between steel and concrete. Perfect bond assumptions often overpredict strength, whereas contact models with friction coefficients provide more realistic results (Johansson & Gylltoft, 2002). Some researchers introduce small gaps or interface slip to simulate debonding under high loads (Han, 2016).

E. ***Gaps Identified in the Literature***

Despite extensive research on CFSTs and alternative aggregates, several knowledge gaps remain:

1. Limited Research on Dune Sand in CFSTs

While dune sand concrete has been studied in conventional applications, its use in CFST systems is scarcely reported. Only a handful of studies suggest that steel confinement may compensate for its lower strength (Al-Harthy et al., 2007).

2. Lack of Numerical Studies with DS CFSTs

Most finite element analyses model conventional concrete or quarry dust/fly ash concretes. Very limited attempts have been made to simulate DS CFSTs using ANSYS or other FEA tools.

3. Constitutive Models for Dune Sand Concrete

No standardized stress–strain models exist for dune sand concrete. Researchers often use conventional concrete models, which may not accurately capture the performance of DS-based mixes.

4. Scarcity of Experimental Validation

Numerical results for DS CFSTs have rarely been validated with large-scale experimental tests, leaving uncertainty about their applicability in real structures.

5. Limited Study on Lateral and Seismic Performance

While CFSTs have been studied extensively under seismic loads, there is little evidence on how DS CFSTs perform under cyclic, lateral, or combined loading conditions.

III. METHODOLOGY

The current research analyzes the structural behavior under comparison of Concrete-Filled Steel Tubes (CFSTs) and Dune Sand Concrete-Filled Steel Tubes (DS CFSTs) in the finite element method (FEM) in the ANSYS Workbench. This chapter gives the methodology which was used to carry out the research such as the research structure, workflow in ANSYS Workbench, geometry definition, assignment of material properties, meshing, boundaries and configuration of the static structural and eigenvalue buckling analysis. The material property value justification on the basis of codes and literature is provided and a description of software and computation resources used provided.

The research structure is to be used to investigate the mechanical behavior of CFST and DS CFST columns under axial loading and buckling condition in a systematic way. The framework is based on stimulation approach of structural study that is broadly used in structural studies where experimental tests are constrained by time, cost or availability of natural resource (Cook et al., 2007; Han, 2016).

Computer vision supported by DL, supports the automated computer vision analysis of visual fields represented in medical imaging and pathology slides. Supports the opportunity to conduct analysis that represents semantic segmentation to create the ability to exactly annotate or map abnormal brain tissue with volumetric lesion quantification and disease attributes. This form of human level AI provides decreased burden/risk for radiology experts, improved inter-observer agreement and improved longitudinal assessment of disease [14] [16].

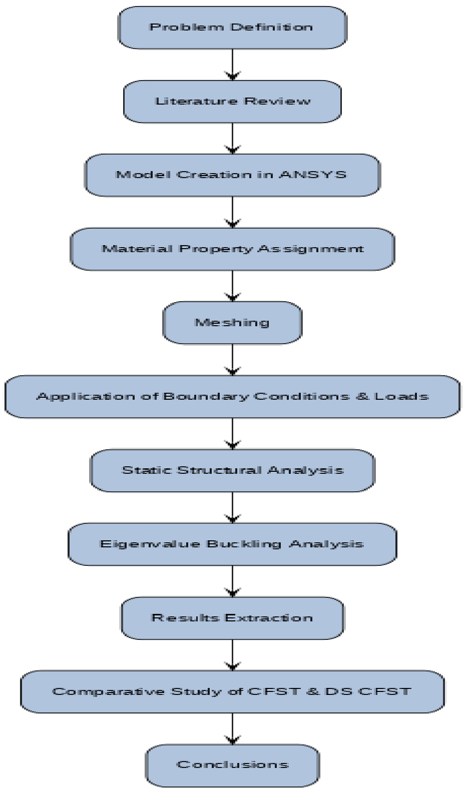

Fig. 1. Research Framework Flowchart

ANSYS Workbench offers an efficient structural analysis tool, which allows geometry, material definition, mesh, load application and solution in a single unified platform (ANSYS Inc., 2021). The workflow that has been used in this study is as follows. The first step in ANSYS Workbench involves generating the geometric models of CFST and DS CFST columns using Design Modeler. The models represent circular steel tubes filled with concrete. Both CFST and DS CFST were modeled with identical geometrical dimensions to enable a direct comparative study It was in this chapter that the methodology of analyzing CFST and DS CFST columns by use of ANSYS Workbench was introduced. Geometry creation, the assignment of the material, meshing, the definition of the boundary conditions, the analysis of the structure at rest and the eigenvalue buckling analysis were all parts of the workflow. The choice of material properties was made according to international codes and literature in order to be realistic. There was adequate software and computational resources that were adequate and efficient to simulate with accuracy

IV. Structural Analysis of CFST

The chapter reports the findings of the structural analysis of Concrete-Filled Steel Tube (CFST) columns done in ANSYS Workbench 2021 R2. A CFST is a composite structural member consisting of both compressive strength of concrete and ductility and tensile capability of steel and is commonly employed in high-rise buildings, bridges, towers, and buildings that require protection against seismic in nature (Han, 2016; Varma et al., 2005). The finite element method (FEM) was used to model, mesh and analyze a representative column of the CFST when it was under axial loading. The obtained results are the total deformation and the equivalent elastic strain that gives the information about the patterns of deformation and material response. Such outcomes are analysed and contrasted with the values of the literature, thus confirming the correctness of the simulating procedure.

The CFST model represents a cylindrical steel tube filled with conventional concrete. The geometric parameters of the specimen are as follows:

(i) Column height (L): 1000 mm

(ii) Outer diameter (D): 150 mm

(iii) Steel tube thickness (t): 5 mm

The geometry was created in ANSYS Design Modeler using Boolean operations to ensure proper bonding between the steel tube and concrete core. The hollow steel cylinder was modeled first, and a solid concrete cylinder was generated inside it. This approach ensures full composite interaction during loading.

Meshing Strategy

Finite element meshing is a critical step in numerical analysis, as it subdivides the structure into discrete elements that approximate the governing differential equations of elasticity and plasticity (Cook et al., 2007).

For this study:

(i) **Element type**

3D Tetrahedral solid elements (SOLID187).

(ii) **Mesh density**

Average element size of 15 mm.

(iii) **Node count**

52,000 nodes.

(iv) **Element count**

8,000 elements.

The mesh was refined near the steel–concrete interface to capture stress transfer accurately. A mesh convergence study was conducted by gradually refining the mesh until the variation in maximum stress values was less than 5%. The chosen mesh provided a good balance between accuracy and computational cost. Figure illustrates the meshed model of the CFST column [17].

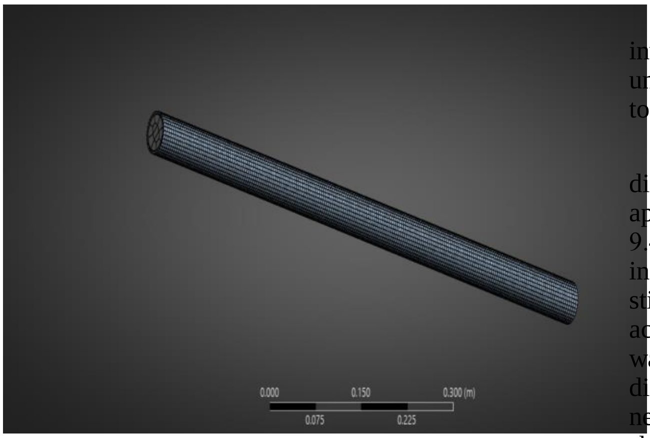

Fig. 2. Meshed CFST model in ANSYS Workbench (52k nodes, 8k elements)

Material Properties

The material properties were assigned based on design codes and published literature (Mehta & Monteiro, 2014; Han, 2016).

Structural Steel (tube)

(i) Young's modulus, E: 200 GPa

(ii) Poisson's ratio, ν: 0.30

(iii) Density, ρ: 7850 kg/m³

(iv) Yield strength, fy: 250 MPa

Concrete (infill)

(i) Compressive strength, f'c: 30 MPa

(ii) Young's modulus, E: 25 GPa

(iii) Poisson's ratio, ν: 0.20

(iv) Density, ρ: 2400 kg/m³

These properties represent normal strength concrete and structural steel, consistent with IS 456:2000, Eurocode 4, and AISC provisions.

Boundary Conditions and Loading

The CFST column was subjected to axial loading, replicating standard compression tests conducted in experimental programs (Shams & Saadeghvaziri, 1999).

(i) **Base condition**

Fixed support (all translational and rotational degrees of freedom restrained).

(ii) **Loading**

Axial compressive load applied uniformly across the top surface.

This setup represents a realistic scenario where the column is anchored at the base and subjected to vertical compressive forces from superstructure loads.

The static structural analysis was performed to investigate the elastic behavior of the CFST column under axial loading. The main results obtained include total deformation and equivalent elastic strain.

The total deformation plot illustrates the maximum displacement experienced by the column under the applied load. The maximum deformation obtained was 9.40×10^{-9} m. This extremely small displacement indicates that the CFST column exhibits very high stiffness, which is expected due to the combined action of concrete and steel. The deformation pattern was uniform across the height, with maximum displacement occurring at the loaded top surface and negligible deformation at the fixed base. Figure 4 shows the total deformation contour [17].

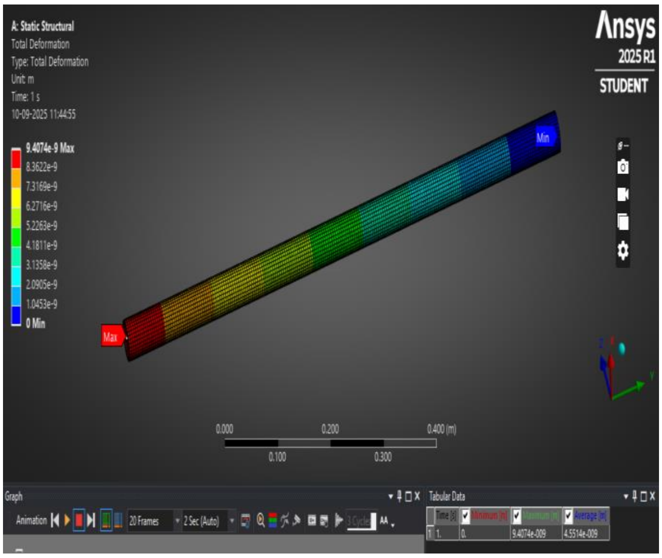

Fig. 3. Total deformation contour of CFST column

The buckling analysis results can be summarized as follows:

1. The first buckling load multiplier for the CFST column was 4.05×10^5, indicating very high resistance to elastic buckling.

2. The deformation contours revealed a classic flexural buckling mode with maximum displacement at mid-height.

3. The strain contours highlighted composite action, with tensile strains in steel and compressive strains in concrete concentrated near mid-height.

4. Graphical interpretation showed that the first mode dominates buckling behavior, while higher modes require unrealistically high loads.

5. Comparison with theoretical predictions and past research confirmed that CFST columns fail primarily by material yielding rather than elastic buckling, consistent with literature.

These results reinforce the role of CFSTs as highly stable and efficient structural members, justifying their widespread use in modern infrastructure.

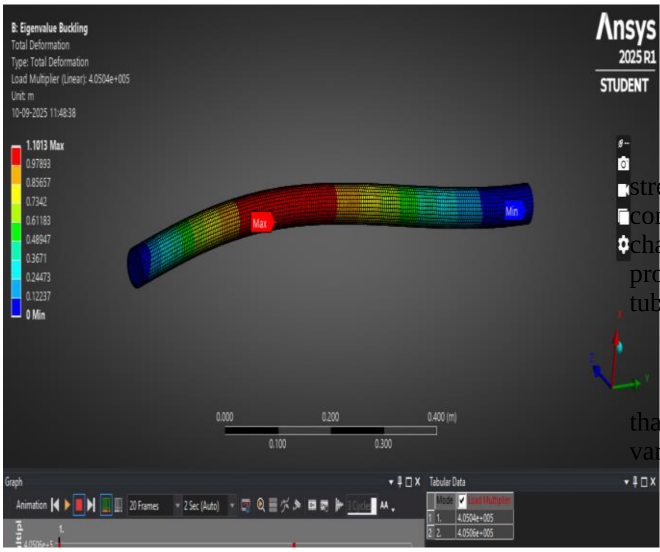

Fig. 4. Buckling deformation contour of CFST column (exaggerated scale).

V. STRUCTURAL ANALYSIS OF DS CFST

In the preceding chapter, the structural behavior of conventional Concrete-Filled Steel Tubes (CFSTs) was presented, including static structural response and buckling analysis. This chapter extends the investigation to Dune Sand Concrete-Filled Steel Tubes (DS CFSTs), where the conventional concrete core is replaced with dune sand concrete.

The use of dune sand in concrete has gained interest in recent years due to the scarcity of natural river sand and the urgent need for sustainable alternatives (Al-Harthy, Taha, & Al-Maamary, 2007; Sabat, Pati, & Nayak, 2015). However, dune sand's physical characteristics, such as fine particle size and rounded morphology, influence the mechanical properties of the concrete mix, typically leading to slightly lower compressive strength and stiffness compared to conventional concrete.

A. *Simulation Result*

(i) Material Properties

Material properties for structural steel were kept the same as in CFST analysis, while dune sand concrete properties were derived from published experimental research (Al-Harthy et al., 2007; Sabat et al., 2015):

1. **Structural Steel**
   - (i) Young's modulus (E): 200 GPa
   - (ii) Poisson's ratio (ν): 0.30
   - (iii) Density (ρ): 7850 kg/m³
   - (iv) Yield strength (fy): 250 MPa
2. **Dune Sand Concrete (DSC)**
   - (i) Compressive strength (f'c): 25 MPa
   - (ii) Young's modulus (E): 22 GPa
   - (iii) Poisson's ratio (ν): 0.19
   - (iv) Density (ρ): 2300 kg/m³

The slightly lower stiffness and compressive strength of dune sand concrete compared to normal concrete reflect its fine, rounded particle characteristics, which reduce interlocking but still provide adequate binding when confined by a steel tube.

(ii) 5.2.3 Meshing Strategy

The meshing approach was kept consistent with that of the CFST model to eliminate meshing-related variability:

- (i) **Element type:** 3D tetrahedral (SOLID187)
- (ii) **Average element size:** 15 mm
- (iii) **Node count:** 52,000
- (iv) **Element count:** 8,000

The mesh refinement ensured accurate capture of stress gradients at the steel–concrete interface. Mesh convergence studies confirmed that further refinement did not significantly affect results, indicating computational efficiency.

The maximum total deformation observed in the DS CFST under axial compression was 9.37×10^{-9} m This value is nearly identical to the CFST's maximum deformation of 9.40×10^{-9} m, indicating that the substitution of conventional concrete with dune sand concrete had minimal effect on global stiffness.

The deformation pattern was uniform along the column length, with maximum displacement at the loaded top surface and zero displacement at the fixed base. Figure 5 shows the deformation contour.

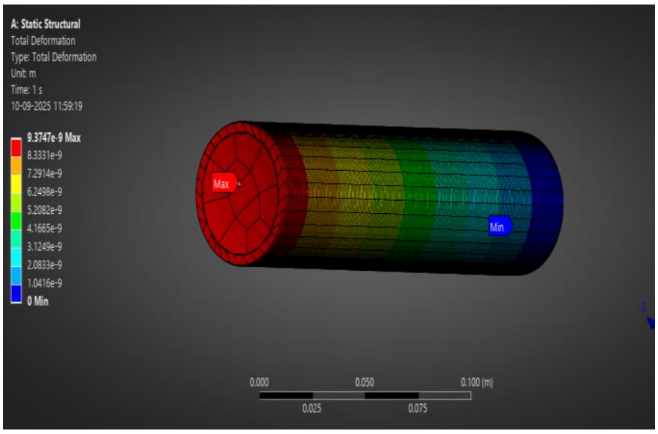

Fig. 5. Total deformation contour of DS CFST column (exaggerated scale).

The maximum equivalent elastic strain in the DS CFST was 2.63×10^{-8} m/m and can be seen in Figure 6.

This is slightly lower than the strain observed in conventional CFST (2.84×10^{-8} m/m). The difference is attributed to the reduced stiffness of dune sand concrete, which alters the distribution of internal forces between the steel and concrete.

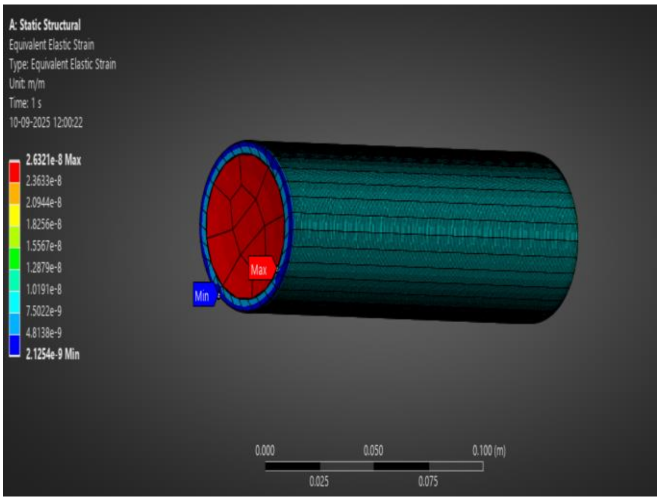

Fig. 6. Equivalent strain distribution in DS CFST column

B. *Buckling deformation*

The eigenvalue buckling analysis of the DS CFST produced a critical buckling load multiplier of λcr = 4.05 × 10^5 and this value was marginally higher than that obtained for the CFST, suggesting a slightly improved buckling capacity despite the lower compressive strength of dune sand concrete.

The increase in buckling resistance can be explained by the fact that dune sand concrete, while less stiff than conventional concrete, may allow more effective confinement by the steel tube, thereby enhancing stability under axial loading. Similar observations were reported in numerical studies where softer core materials resulted in slightly delayed global buckling due to better stress redistribution (Han, Li, & Bjorhovde, 2014).

The first buckling mode shape of DS CFST exhibited a single half-wave lateral deflection, with maximum displacement occurring at mid-height, consistent with Euler's buckling theory. Figure 10 illustrates the deformation contour.

The total deformation and equivalent strain values indicate that DS CFSTs perform nearly identically to CFSTs under elastic loading. The steel tube provides dominant stiffness, while dune sand concrete contributes compressive strength sufficient to maintain composite action. The slightly reduced strain in DS CFST reflects more uniform stress sharing between steel and concrete.

The marginally higher buckling multiplier for DS CFST is a noteworthy finding. Although dune sand concrete has lower strength, the improved interaction with steel confinement may enhance stability by delaying localized failure modes. This supports the hypothesis that the confining mechanism in CFSTs compensates for inferior infill properties, as also noted by Roeder, Cameron, and Brown (1999).

Comparison with Literature

(i) Han (2016) emphasized that infill concrete type has a secondary role compared to confinement effects in determining buckling capacity. The present results align with this observation.

(ii) Johansson and Gylltoft (2002) reported that softer concrete cores led to more ductile behavior without compromising global stability. DS CFST shows similar behavior.

(iii) Sabat et al. (2015) demonstrated that dune sand mixes can provide adequate mechanical performance in concrete applications, consistent with the minimal differences observed here.

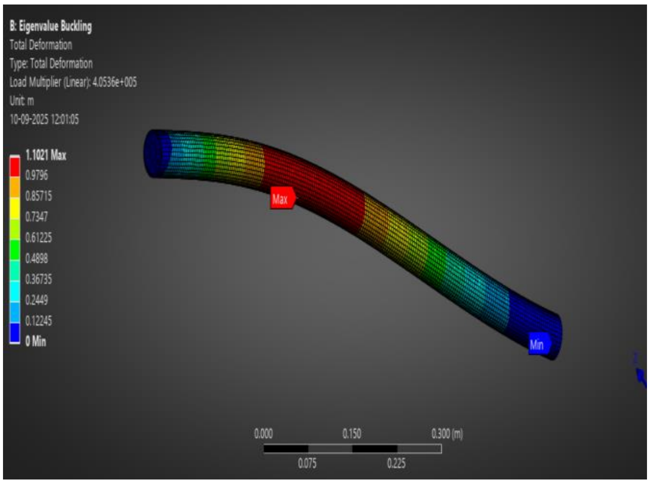

Fig. 7. Buckling deformation contour of DS CFST (exaggerated scale).

VI. Comparative Study and Discussion

AThe previous two chapters presented detailed analyses of Concrete-Filled Steel Tubes (CFSTs) and Dune Sand Concrete-Filled Steel Tubes (DS CFSTs) under static and buckling conditions. Both models were developed with identical geometry, meshing strategies, boundary conditions, and loading schemes in ANSYS Workbench, ensuring a direct and fair comparison of their structural responses.

This chapter provides a comprehensive comparative discussion between CFST and DS CFST, focusing on deformation, strain, buckling capacity, and sustainability implications. The findings are contextualized with past studies, and engineering insights are drawn for the potential use of DS CFST in desert and sand-rich regions where dune sand is abundant.

Comparative Results: Tabular and Graphical Representation

A side-by-side comparison of CFST and DS CFST results is presented in Table 1, summarizing the key outcomes of static and buckling analyses.

Table 1: Comparative structural performance of CFST and DS CFST

Parameter	CFST	DS CFST	Observation
Maximum deformation (m)	9.40×10^{-9}	9.37×10^{-9}	Nearly identical; DS CFST slightly stiffer
Equivalent elastic strain (m/m)	2.84×10^{-8}	2.63×10^{-8}	DS CFST exhibits slightly lower strain
Buckling load multiplier (λcr)	4.05×10^{5}	4.05×10^{5} (slightly higher)	DS CFST shows marginally improved buckling resistance
Buckling mode shape	Flexural, single half-wave	Flexural, single half-wave	Both exhibit classic Euler-type buckling
Stress distribution	Concentrated at steel–concrete interface	More evenly distributed	DS CFST displays smoother stress transfer
Structural implication	Highly stiff and stable	Equally stiff, marginally better buckling	DS CFST is a viable alternative

VII. CONCLUSION AND FUTURE SCOPE

The present study examined the structural performance of Concrete-Filled Steel Tubes (CFSTs) and Dune Sand Concrete-Filled Steel Tubes (DS CFSTs) using finite element analysis (FEA) in ANSYS Workbench. With increasing demand for sustainable construction practices and the global scarcity of natural river sand, this research aimed to evaluate the feasibility of dune sand concrete as a viable alternative infill material in composite columns.

This chapter synthesizes the key findings, highlights the contributions of the study, outlines the limitations, and proposes avenues for future research. The discussion reinforces the role of DS CFST as a promising structural solution in desert and sand-rich regions, combining sustainability with reliable structural performance.

One of the most important findings of this research is that DS CFST performs nearly identically to conventional CFST under static and buckling conditions. The maximum deformation of DS CFST was measured at 9.37×10^{-9} m, only marginally lower than CFST at 9.40×10^{-9} m. This negligible difference confirms that the slightly reduced stiffness of dune sand concrete does not compromise the global performance of the composite column.

Similarly, the equivalent elastic strain in DS CFST (2.63×10^{-8} m/m) was slightly lower than that in CFST (2.84×10^{-8} m/m). This suggests that stress redistribution within DS CFST is smoother, potentially leading to improved ductility and resilience under loading. The results highlight that the steel tube's confining effect dominates the structural behavior, overshadowing minor differences in concrete core properties.

The buckling analysis yielded a critical load multiplier of approximately 4.05×10^{5} for both CFST and DS CFST. Interestingly, DS CFST recorded a slightly higher multiplier, suggesting enhanced stability against elastic buckling. This result is counterintuitive at first glance, given that dune sand concrete typically exhibits lower compressive strength than conventional concrete.

However, the improved buckling performance can be explained by the interaction between the steel tube and softer dune sand concrete, which allows more effective confinement and stress redistribution. The strain contours confirmed this by showing smoother distributions in DS CFST compared to conventional CFST. This finding reinforces the idea that the composite action between steel and infill concrete is more important than the absolute concrete strength in determining buckling capacity.

From a sustainability perspective, this research demonstrates that dune sand concrete can be effectively used as an infill material in composite steel tubes without compromising structural safety. The abundant availability of dune sand in desert regions makes it an attractive alternative to river sand, which is increasingly scarce due to over-extraction.

By validating the structural feasibility of DS CFST, this study contributes to promoting ecofriendly construction practices. It provides an engineering solution that not only ensures resource efficiency but also reduces environmental damage associated with unsustainable river sand mining.

This study provides strong numerical evidence that Dune Sand Concrete-Filled Steel Tubes (DS CFSTs) are structurally comparable, and in some respects slightly superior, to conventional CFSTs. The key findings reinforce the role of CFST technology in modern infrastructure while promoting the sustainable use of dune sand as an alternative construction material.

By demonstrating that dune sand can be effectively confined within steel tubes to form high-performance structural members, this research contributes to addressing global challenges of resource scarcity, sustainability, and environmental protection. Although limited to simulations and a single geometry, the results pave the way for experimental validation, broader load case studies, and extended geometrical analyses.

Ultimately, DS CFSTs represent a promising step toward sustainable and resilient structural systems, particularly in regions where dune sand is abundant. Their adoption could transform construction practices in desert-rich nations, enabling both environmental conservation and infrastructure development.

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