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AN EXPERIMENTAL STUDY ON WOODEN PILES UNDER AXIAL LOADING SUSTAINABLE FOUNDATION SYSTEM

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Abstract - *Rapid urban development in weak and medium soil conditions requires sustainable and economical foundation systems. This study investigates the behavior of eco-friendly wooden piles under axial loading conditions. Treated timber piles were selected as an alternative to conventional concrete and steel piles due to their low environmental impact and cost effectiveness. A Finite Element Model (FEM) was developed to analyze pile–soil interaction and settlement behavior. Load– settlement analysis was carried out to evaluate the bearing capacity and deformation characteristics of wooden piles. The results indicate that treated wooden piles provide satisfactory performance with controlled settlement in medium soil conditions. The study concludes that wooden piles can be used as sustainable foundation systems for light and medium load structures.*

Keywords: Wooden piles, Sustainable foundation, FEM, Soil settlement, Eco-friendly piles, Load–settlement analysis.

1. INTRODUCTION

Weak and medium strength soils often create challenges in foundation construction due to excessive settlement and low bearing capacity. Pile foundations are commonly adopted in such conditions to transfer structural loads safely to deeper soil layers. Conventional pile materials such as concrete and steel increase construction cost and environmental impact. Therefore, sustainable and eco-friendly foundation alternatives are becoming increasingly important in modern civil engineering practice.

Wooden piles are one of the oldest deep foundation systems used in construction. Timber is a renewable material with low carbon emission, lightweight characteristics, and economical advantages. Modern preservative treatment techniques improve the durability and resistance of wooden piles against moisture, fungi, and biological attack, making them suitable for foundation applications.

This study focuses on analyzing the behavior of treated wooden piles under axial loading conditions in medium soil environments. Finite Element Modelling (FEM) was used to predict soil settlement and evaluate pile–soil interaction behavior. Load–settlement analysis was performed to assess the suitability of wooden piles as sustainable foundation systems for civil engineering structures.

2. Problem Statement

Weak and medium soil conditions often create problems such as excessive settlement and reduced bearing capacity in foundation systems. Conventional concrete and steel piles increase construction cost and contribute to environmental pollution through high carbon emissions. Therefore, sustainable and economical alternatives are required in modern construction practice.

Treated wooden piles can provide an eco-friendly foundation solution with satisfactory structural performance, reduced environmental impact, and economical construction benefits.

3. Objectives

- To study the behavior of wooden piles under axial loading conditions.
- To evaluate the load carrying capacity of wooden piles.
- To analyze the settlement behavior of pile foundations in medium soil conditions.

- To develop a Finite Element Model (FEM) for pile– soil interaction analysis.
- To study the suitability of treated wooden piles for sustainable foundation applications.
- To evaluate load–settlement characteristics of wooden piles.

4. Need for Sustainable Foundation Systems

Rapid urbanization and infrastructure development increase the demand for environmentally sustainable construction materials. The construction industry contributes significantly to carbon emissions due to excessive use of concrete and steel. Sustainable foundation systems using renewable materials can reduce environmental impact and support green construction practices.

Wooden piles are renewable, biodegradable, and economical foundation elements. Modern preservative treatments improve their durability and make them suitable for foundation applications in weak and medium soil conditions.

5. Literature Review

Several researchers have studied the behavior of pile foundations under different loading conditions. Timber piles were traditionally used in coastal regions, bridge foundations, and low-rise structures due to their economical and renewable nature.

Bowles explained the importance of settlement analysis and bearing capacity evaluation in pile foundation design. Tomlinson studied axial load transfer mechanisms in pile foundations and highlighted the role of skin friction and end bearing resistance.

Recent studies showed that Finite Element Modelling (FEM) provides better prediction of soil settlement and pile deformation characteristics compared to conventional analytical methods. Modern preservative treatment methods significantly improve the durability and service life of timber piles by protecting them against moisture and biological deterioration.

The literature review indicates that treated wooden piles can provide satisfactory performance in weak and medium soil conditions while supporting sustainable construction practices.

6. Scope of the Study

The scope of this study includes:

- Analysis of wooden piles under axial loading conditions.
- Evaluation of settlement behaviour in medium soil.
- Development of Finite Element Model (FEM).
- Load–settlement analysis of wooden piles.
- Study of sustainable foundation applications.
- Assessment of treated timber pile performance.

7. Materials and Soil Properties

7.1 Timber Material

Timber was selected as the pile material due to its renewable nature, low cost, and environmental benefits. The important properties considered include:

- Density
- Moisture content
- Compressive strength
- Elastic modulus
- Durability

Modern preservative treatment methods were considered to improve resistance against:

- Fungal decay
- Moisture attack
- Termite attack
- Biological deterioration

7.2 Soil Properties

The soil properties considered for analysis are listed below:

Property	Value
Soil Type	Medium Clay Soil
Unit Weight	18 KN/m^3
Cohesion	25 kPa
Angle of Internal Friction	28°
Young's Modulus	20 MPa
Poisson's Ratio	0.3

8. Methodology

The methodology adopted in this study involves the analysis of wooden piles under axial loading conditions using theoretical and numerical approaches. Suitable timber material and soil properties were selected for the study. Preservative treatments were reviewed to improve the durability of wooden piles.

A Finite Element Model (FEM) was developed to analyze pile–soil interaction and settlement behavior. Axial compressive loads were applied on the wooden pile, and the corresponding settlement values were obtained through analysis. Load versus settlement curves were generated to evaluate the bearing capacity and deformation characteristics of the pile foundation system.

The methodology includes:

1. Selection of timber material
2. Collection of soil properties
3. Development of FEM model
4. Application of axial loads
5. Settlement analysis
6. Generation of load–settlement curves
7. Interpretation of results

9. Finite Element Modelling (FEM)

A Finite Element Model (FEM) was developed to study the behavior of wooden piles under axial loading conditions. The pile and surrounding soil were modelled using suitable material properties and boundary conditions.

The modelling process included:

- Creation of pile geometry
- Definition of soil domain
- Assignment of material properties
- Meshing of elements
- Application of axial loads
- Settlement analysis

The FEM analysis helped in predicting:

- Stress distribution
- Soil deformation
- Settlement behavior
- Pile–soil interaction

The developed numerical model provided effective prediction of wooden pile performance under different loading conditions.

10. Axial Load and Settlement Analysis

Axial compressive loads were applied gradually on the wooden pile foundation system. The corresponding settlement values were observed and recorded. The relationship between load and settlement was represented using a load–settlement curve.

The analysis showed that settlement increased gradually with increase in applied load. Initially, the pile behaved elastically with small settlement values. At higher loading conditions, settlement increased due to increased stress concentration in the surrounding soil.

The load–settlement curve helped in evaluating:

- Ultimate bearing capacity
- Deformation characteristics
- Stability of foundation system
- Settlement performance

The results indicate that treated wooden piles can effectively support light and medium structural loads with controlled settlement behavior.

Fig. 1 Load – settlement curve for wooden pile

Fig. 1 shows the load–settlement behavior of the wooden pile under axial loading conditions. Initially, the pile exhibits elastic behavior with low settlement values. As the applied load increases, settlement gradually increases due to stress concentration in the surrounding soil. The curve indicates that treated wooden piles provide stable performance under moderate loading conditions.

11. Practical Applications

Treated wooden piles can be effectively used in:

- Residential buildings.
- Rural infrastructure projects.
- Temporary structures.
- Coastal foundation systems.
- Bridge substructures.
- Sustainable construction projects.

12. Results and Discussion

The results obtained from FEM analysis showed that wooden piles provide satisfactory performance under axial loading conditions in medium soil environments.
Important observations include:

- Settlement increased with increase in axial load.
- Soil stiffness significantly influenced pile behavior.
- Load transfer occurred through skin friction and end bearing resistance.
- Treated timber piles showed improved durability and stability.
- FEM effectively predicted settlement characteristics.

The load–settlement analysis confirmed that wooden piles can be used as sustainable and economical alternatives to conventional pile materials for suitable construction applications.

13. Advantages of Wooden Piles

- Eco-friendly foundation material
- Renewable construction resource
- Economical compared to steel and concrete piles
- Easy handling and transportation
- Reduced environmental impact
- Suitable for weak and medium soil conditions
- Low carbon footprint

14. Conclusion

This study investigated the behavior of wooden piles under axial loading conditions using Finite Element Modelling (FEM). The results showed that treated wooden piles provide satisfactory load carrying capacity and controlled settlement behavior in medium soil conditions.
The developed FEM model successfully predicted soil settlement and pile–soil interaction characteristics. Load– settlement analysis indicated stable foundation performance under moderate loading conditions.
The study concludes that treated wooden piles can be effectively used as sustainable, economical, and eco-friendly foundation systems for light and medium load civil engineering structures.

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