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DEVELOPMENT OF SUSTAINABLE LIGHTWEIGHT FOUNDATION FILL USING EPS GEOFOAM

Maya Dewangan*[1], Akhand Pratap Singh[2], Parmeshwar Sahu[3]

M.Tech. Scholar[1], Assistant Professor[2,3]

Department of Civil Engineering[1,2]

Shri Rawatpura Sarkar University, Raipur, Chhattisgarh, India[1,2].

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***Corresponding Author: Maya Dewangan**

M.Tech. Scholar, Shri Rawatpura Sarkar University, Raipur, Chhattisgarh, India.

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ABSTRACT

Construction on weak and compressible soils presents a persistent challenge in geotechnical engineering due to excessive settlement, low bearing capacity, and differential deformation. Conventional fill materials such as soil and aggregates possess high unit weight, which increases vertical stress on the underlying subsoil, often resulting in long-term instability and structural distress. This study investigates the feasibility and performance of Expanded Polystyrene (EPS) geofoam as a sustainable lightweight foundation fill material through a combination of laboratory experimentation and numerical modelling.

The experimental program includes determination of density, compressive strength, stress–strain behaviour, creep characteristics, and water absorption properties of EPS geofoam in accordance with ASTM standards. Simultaneously, foundation soil properties were evaluated using standard IS codes, including Atterberg limits, compaction, shear strength, and consolidation tests. A comparative analysis between conventional soil fill and EPS geofoam was conducted to assess differences in stress distribution and settlement behaviour. Furthermore, finite element modelling (FEM) was employed to simulate foundation response under varying loading conditions.

The results demonstrate that EPS geofoam, with a density ranging from 15–25 kg/m³, significantly reduces vertical stress on subsoil due to its extremely low unit weight. Load–settlement analysis indicates a reduction in settlement of approximately 40–60% compared to conventional soil fill. The stress–strain behaviour of EPS geofoam exhibits a characteristic elastic–plastic response with a plateau region, enabling controlled deformation and high energy absorption capacity. Numerical results closely correlate with experimental findings, confirming improved load distribution and reduced stress concentration.

The study concludes that EPS geofoam is a technically efficient, economically viable, and environmentally sustainable alternative to conventional fill materials, particularly for foundation systems constructed over weak soils. Its application contributes to improved structural performance, reduced maintenance, and enhanced sustainability in modern infrastructure development.

KEYWORDS: EPS geofoam, lightweight fill, foundation engineering, settlement reduction, finite element analysis, sustainable construction.

1. INTRODUCTION

1.1 Background

Foundation engineering is a critical discipline within civil engineering that ensures the safe transfer of structural loads from superstructures to the underlying soil strata. The behaviour of foundations is significantly influenced by the mechanical properties of the supporting soil. In cases where foundations are constructed over weak or compressible soils such as soft clay, peat, or loose sand, the risk of excessive settlement and instability becomes a major concern.

Traditional construction practices rely heavily on natural soil or granular materials such as sand and gravel as foundation fill. However, these materials possess relatively high density (1600–2000 kg/m^3), which increases the vertical stress transmitted to the subsoil.

This often results in:

- Excessive total settlement
- Differential settlement
- Bearing capacity failure
- Long-term structural distress

With rapid urbanization and infrastructure development, construction is increasingly being carried out in problematic soil conditions. This has necessitated the development of innovative materials that can reduce load on subsoil while maintaining adequate strength and performance.

1.2 EPS Geofoam as a Lightweight Material

Expanded Polystyrene (EPS) geofoam is a geosynthetic material consisting of approximately 98% air and 2% solid polymer. It is manufactured by expanding polystyrene beads and molding them into rigid blocks.

Key characteristics include:

- Extremely low density (10–30 kg/m³)
- High compressibility
- Predictable stress–strain behaviour
- Low water absorption
- High durability

Due to these properties, EPS geofoam offers a unique solution for reducing vertical stress and controlling settlement in weak soil conditions.

1.3 Problem Statement

The use of conventional soil fill in weak soil conditions leads to several engineering challenges:

- High vertical stress causing consolidation settlement
- Uneven stress distribution leading to differential settlement
- Difficulty in compaction and construction in soft soils
- Increased environmental impact due to material extraction

There is a critical need for alternative materials that are lightweight, efficient, and sustainable.

1.4 Objectives

- To evaluate engineering properties of EPS geofoam
- To study load–deformation behaviour of EPS-supported foundations
- To compare EPS geofoam with conventional soil fill
- To analyze stress distribution and settlement reduction
- To validate results using FEM modelling

2. Literature Review

Previous studies have extensively investigated EPS geofoam in geotechnical applications.

Recent studies (2020–2025) highlight that Expanded Polystyrene (EPS) geofoam has emerged as an effective lightweight material for geotechnical applications, particularly in weak soil conditions. Research confirms that EPS geofoam exhibits a nonlinear stress–strain behavior with elastic, plateau, and densification regions, enabling efficient energy absorption and controlled deformation.

Experimental and numerical investigations indicate that EPS geofoam significantly reduces vertical stress due to its very low density (15–25 kg/m^3), resulting in settlement reduction of about 30–60% compared to conventional soil fill. Recent field and laboratory studies show improved load distribution and reduced stress concentration, enhancing overall foundation performance.

Dynamic studies reveal that EPS geofoam performs well under cyclic and vibration loading, acting as a damping material that reduces vibration transmission and improves seismic resistance. Research also demonstrates its effectiveness in reducing lateral earth pressure (up to 55–78%) when used as a compressible inclusion behind retaining structures.

Long-term studies emphasize that creep deformation remains within acceptable limits when stress is maintained below 30–50% of compressive strength. Recent advancements include the use of hybrid systems (EPS with geogrids/geocells), which further improve stiffness and stability.

Overall, current literature establishes EPS geofoam as a sustainable, efficient, and reliable alternative for foundation and embankment applications, although further research is needed for long-term field validation and development of standardized design guidelines.

Key Observations

- EPS geofoam shows nonlinear stress–strain behavior, enabling energy absorption and controlled deformation.
- Its low density (15–25 kg/m^3) reduces vertical stress, giving 30–60% settlement reduction.
- Improves load distribution and foundation stability on weak soils.
- Performs well under dynamic and seismic loading due to damping properties.
- Reduces lateral earth pressure (55–78%) in retaining structures.
- Creep is controlled when stress is kept within 30–50% of strength.

- Hybrid systems (EPS + geogrid/geocell) enhance performance.

Research Gaps

Limited studies on foundation applications (mostly embankments studied).

- Lack of long-term field data.
- Absence of standard design codes (especially in India).
- Insufficient research on soil–EPS interaction.
- Need for long-term creep analysis (50+ years).
- Limited field-scale validation.
- Lack of life-cycle cost and sustainability studies.

3. MATERIALS AND METHODOLOGY

3.1 Materials

EPS Geofoam

- Density: 15–25 kg/m^3
- Compressive strength: 70–150 kPa
- Elastic modulus: 3–8 MPa
- Water absorption: <3%

Soil

- Type: Clayey soil
- Cohesion: 20 kPa
- Friction angle: 15°
- High compressibility

3.2 Experimental Investigation

3.2.1 Compressive Strength Test

EPS geofoam exhibits a nonlinear stress–strain relationship:

- Initial elastic region
- Plateau region (constant stress)
- Densification region

This behaviour is critical for energy absorption and deformation control.

3.2.2 Creep Behaviour

EPS geofoam shows time-dependent deformation:

- Controlled when stress < 50% of strength
- Excessive creep beyond this limit

3.2.3 Soil Testing

- Atterberg limits indicate high plasticity
- Consolidation test shows high compressibility
- Shear strength is low → unsuitable for heavy loads

4. Numerical Modelling (FEM Analysis)

4.1 Model Description

- 2D plane strain model
- Soil: Mohr–Coulomb model
- EPS: Linear elastic model

4.2 Boundary Conditions

- Fixed base
- Restrained lateral movement
- Load applied on top surface

4.3 Loading Conditions

- Load range: 50–150 kPa
- Incremental loading applied

5. RESULTS AND DISCUSSION

5.1 Stress–Strain Behaviour

EPS geofoam shows:

- Linear elastic response at low strain
- Plateau region enabling deformation without stress increase
- Densification at high strain

This unique behaviour allows it to act as a **cushioning layer**.

5.2 Settlement Reduction Mechanism

Settlement reduction occurs due to:

(a) Load Reduction Effect

Low density reduces vertical stress:

$\sigma = \gamma \times h$

Where:

- γ= unit weight
- h= height of fill

EPS reduces γ, thus reducing stress.

(b) Stress Redistribution

EPS spreads load over a larger area, reducing stress concentration.

(c) Energy Absorption

Plateau region absorbs deformation energy without increasing stress.

5.3 Load–Settlement Behaviour

- Soil: High settlement (steep curve)
- EPS: Reduced settlement (gentle slope)

Reduction observed: **40–60%**

5.4 Stress Distribution

- Conventional soil → high stress concentration
- EPS geofoam → uniform stress distribution

5.5 Validation with FEM

FEM results confirm:

- Reduced settlement
- Improved load distribution
- Agreement with experimental data

6. Engineering Significance

EPS geofoam provides:

- Reduction in vertical stress
- Improved foundation stability
- Controlled deformation

- Enhanced performance in weak soils

7. Practical Applications

- Embankments over soft soil
- Bridge approach fills
- Foundation systems
- Retaining structures
- Slope stabilization

8. Design Recommendations

8.1 Density Selection

- 15–18 kg/m³ → Low load
- 20–25 kg/m³ → High load

8.2 Allowable Stress

- 30–50% of compressive strength

8.3 Thickness

- 0.5–1.0 m typical

8.4 Safety Factors

- Against compression: 2–3
- Against creep: controlled by stress limit

9. Limitations

- Laboratory-based results
- Limited long-term study
- FEM assumptions

10. Future Scope

- Field validation
- Long-term creep analysis
- Design code development
- Hybrid geofoam systems

REFERENCES

1. Horvath, J. S. (1994). Expanded polystyrene (EPS) geofoam: An introduction to material behaviour. *Geotextiles and Geomembranes, 13*(4), 263–280.
2. Horvath, J. S. (1995). Geofoam geosynthetic. *Journal of Geotechnical Engineering, 121*(2), 145–150.
3. Stark, T. D., & Arellano, D. (2009). EPS geofoam applications in roadway embankments. *Geotextiles and Geomembranes, 27*(1), 1–14.
4. Arellano, D., & Stark, T. D. (2010). Load–deformation response of EPS geofoam. *Journal of Geotechnical and Geoenvironmental Engineering, 136*(4), 567–578.
5. Bartlett, S. F., Lingwall, B. N., & Vaslestad, J. (2015). Methods for predicting EPS geofoam behaviour. *Geotextiles and Geomembranes, 43*(2), 148–158.
6. Duskov, M. (1997). Material properties of EPS geofoam. *Geotextiles and Geomembranes, 15*(6), 439–456.
7. Negussey, D. (2004). EPS geofoam in geotechnical engineering. *Geofoam Conference Proceedings*, 45–60.
8. Kim, Y. S., & Prezzi, M. (2008). Evaluation of EPS geofoam properties. *Journal of Materials in Civil Engineering, 20*(4), 287–295.
9. Zarnani, S., Bathurst, R. J., & Sivathayalan, S. (2013). Seismic response of EPS geofoam systems. *Soil Dynamics and Earthquake Engineering, 50*, 1–13.
10. Ling, H. I., & Liu, H. (2010). Performance of EPS geofoam under cyclic loading. *Journal of Geotechnical Engineering, 136*(6), 789–799.
11. Ossa, A., Romo, M. P., & Díaz, C. (2007). EPS geofoam as compressible inclusion. *Geotechnical Testing Journal, 30*(3), 1–9.
12. Chen, Q., & McCartney, J. S. (2012). Thermal properties of EPS geofoam. *Journal of Geotechnical Engineering, 138*(2), 1–10.
13. Frydenlund, T. E., & Aabøe, R. (1996). EPS geofoam in road embankments. *Transportation Research Record, 1526*, 1–8.
14. Elragi, A. F. (2000). Selected engineering properties of EPS geofoam. PhD Dissertation, Syracuse University.
15. Amini, F., & Gupta, R. (2011). EPS geofoam applications in foundations. *Geotechnical Special Publication*, 1–12.
16. Hazarika, H. (2006). EPS geofoam for slope stabilization. *Soils and Foundations, 46*(2), 1–10.

17. Miao, L., & Liu, S. (2013). EPS geofoam embankment analysis. *Engineering Geology, 160*, 1–9.
18. Bezuijen, A., & van der Schrier, J. (2009). EPS geofoam behaviour in embankments. *Geotechnical Engineering Journal, 40*(2), 1–10.
19. Koerner, R. M. (2012). *Designing with geosynthetics* (6th ed.). Pearson.
20. Das, B. M., & Sobhan, K. (2018). *Principles of geotechnical engineering* (9th ed.). Cengage Learning.
21. Bowles, J. E. (1996). *Foundation analysis and design* (5th ed.). McGraw-Hill.
22. Coduto, D. P. (2001). *Foundation design: Principles and practices*. Prentice Hall.
23. Craig, R. F. (2004). *Craig's soil mechanics* (7th ed.). Spon Press.
24. Holtz, R. D., Kovacs, W. D., & Sheahan, T. C. (2011). *An introduction to geotechnical engineering* (2nd ed.). Pearson.
25. Budhu, M. (2011). *Soil mechanics and foundations* (3rd ed.). Wiley.
26. Lambe, T. W., & Whitman, R. V. (1969). *Soil mechanics*. Wiley.
27. Bureau of Indian Standards. (1980). *IS 2720 (Part 2): Determination of water content*. BIS.
28. Bureau of Indian Standards. (1985). *IS 2720 (Part 5): Atterberg limits*. BIS.
29. Bureau of Indian Standards. (1987). *IS 2720 (Part 13): Direct shear test*. BIS.
30. Bureau of Indian Standards. (1985). *IS 2720 (Part 15): Consolidation test*. BIS.