Experimental Studies to analyse effect of shape of EPS Geofoam unit cell with flyash

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Abstract. The The Present work is focused on using expanded polystyrene (EPS) as an effective construction material in the field of geotechnical engineering. The study gives an ease of EPS geofoam to be used in combination with other material to form an effective composite material which enhance the properties of material formed. Study precisely reports the engineering behavior of proposed expanded polystyrene (EPS) geofoam unit cell with flyash inside the core of cell. These cells were prepared with two different densities of EPS geofoam material i.e. 14 kg/m^3 and 24 kg/m^3 with heights 50, 60, 75 and 100 mm. Unit cells were cut in to three shapes as square, hexagon and circle. Flyash collected from Koradi Thermal Power Station, Nagpur was compacted inside the core of unit cell at its optimum moisture content in layers of 25 mm height. The compression test were performed on the composite material to study the stress- strain behavior, effect of density of EPS geofoam and height of unit cell along with failure pattern. Compressive stress-strain curve for EPS geofoam showed increase in compressive strength with decreased height for a particular density. Also, increase in the height of EPS geofoam unit cell with flyash results a decrease in compressive strength. The load carrying capacity of hexagonal shape is more than the circular shape and that of circular shape is more than square shape. Different failure patterns were observed for each height of unit cell tested.

Keywords: Expanded Polystyrene, geofoam, flyash, compressive stress, strain

1 Introduction

The Vidharbha region of Maharashtra, India is known for the availability of natural resources such as coal, manganese, and lime along with other minerals. Prominent deposits of coal (≈ 5576.70 million tons) are observed in the districts Nagpur, Chandrapur, Yavatmal, Wardha and all are located in the Vidharbha region [1]. Because of abundant availability of coal, nine medium to large scale thermal power plants are operational and many new power plants are proposed in the region. Contribution of Vidharbha region to the total power generation of the state is substantial. In the year 2017-18, out of 196.44 million tons of total flyash generated in the country, nearly

13 - 14 million tons is produced in the Vidharbha [2]. Overall flyash utilization in different sectors such as cement industry, brick manufacturing, landfilling, road and embankment, dike raising, and other areas has been increased significantly in the recent years but, still, unutilized flyash is being dumped nearby the power plant areas. The large scale generation of such by-product cause problems not only to the environment but also their scientific disposal is of concern. The use of by-product can play a major role in road construction, embankment, as earthfill materials to curb the natural resources depletion problem, environmental deprivation, and energy consumption.

Black cotton soil deposits are quite common in the state of Maharashtra, India, which is having montmorillonite as the predominant clay mineral; possess low strength and high volumetric swelling-shrinkage. Many difficulties are experienced by the engineers during the construction of pavements over these expansive soils. Black cotton soils unable to cater the wheel load due to its poor strength, high seasonal volumetric changes and so, affecting the service life of the pavement. To have the desired performance of the road, treatment of soil subgrade is needed [3].

Expanded polystyrene (EPS) geofoam is characterized as cellular geosynthetic material with high compressibility, high tensile strength, good flexural strength, and rupture strength in shear. It is being used worldwide due to its large number of applications. Expanded Polystyrene (EPS) geofoam is a lightweight material usually in the form of block. The commonly used parameter for EPS geofoam is density. The density of EPS geofoam is very less compared to other conventional fill materials used in the foundation practice.

Interconnected cells in the form of a mattress can be used as soil reinforcement, which will help to substantially increase the load carrying capacity with reduced settlement of the structure to be built. Due to the three-dimensional configuration of the cellular reinforcement, it helps arrest the lateral spreading of infill material and creates a relatively stiffened mat that distributes the load over a larger area on the underlying poor soil, thereby increasing the load carrying capacity [4-7]. In order to enhance the load carrying capacity on black cotton soil, EPS geofoam cellular reinforcement with flyash as the filling material is proposed in the study. This work presents the use of expanded polystyrene (EPS) geofoam in combination with flyash to form an effective composite earth fill material in embankments. This work precisely reports the engineering behavior of proposed expanded polystyrene (EPS) geofoam unit cell with flyash inside the core of cell. These cells were prepared with two different densities of EPS geofoam material i.e. 14 kg/m^3 and 24 kg/m^3 with heights 50, 60, 75 and 100 mm. Unit cells were cut in to three shapes as square, hexagon and circle.

2 Materials

2.1 EPS Geofoam

EPS geofoam unit cells were prepared with simple method by considering the ease of cutting EPS geofoam into required shape and size. The density of EPS geofoam block of size 1 m × 1 m × 0.5 m was determined at R. K. Industries, Nagpur and panels of required dimensions were cut from EPS geofoam block. The design pattern was envisaged and an aluminum stencil was prepared. By using the stencil, the panel of EPS geofoam was cut properly to orient a single strip shape of a unit cell with the required height [4-7, 9-13]. One side of the mold was left cut for the passage of blade which was joined to each other by means of a glue to form a complete shape. The size of strip was adjusted in such a way that it will orient into circular, hexagonal and square shapes. The unit cell was prepared with two different densities of EPS geofoam (14 and 24 kg/m^3) and four different heights (50, 60, 75 and 100 mm). The thickness and pocket size of the EPS geofoam unit cells were kept same.

2.2 Flyash

Flyash for the work was collected from the Electrostatic Precipitator (ESP) of Koradi Thermal Power Station, Nagpur and stored properly to ensure the uniformity in the characteristics of flyash used throughout the study. Physical properties of flyash are given in Table 1. Chemical composition presented in Table 2 depicts that the collected flyash for the work falls under class F category as per ASTM C618 –12a [8].

Table 1. Physical properties of Koradi thermal power plant flyash

Sr. No.	Property	Value
1	Specific gravity	2.13
2	Loss on ignition (LOI) (%)	3.68
3	Water Content (%)	0.08
4	% finer than 75 µm	91.0

Table 2. Chemical composition of flyash

Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	K_2O	MgO	Na_2O	LOI
Concentration (%)	55.58	26.40	3.92	6.71	2.10	1.20	0.59	0.30	3.68

3. Test Setup

The compressive strength tests were conducted on a strain controlled loading frame in the laboratory with a specially modified arrangement. EPS geofoam unit cells is filled with flyash were loaded using rigid steel plates at the top and bottom. The top plate of dimension 150 mm × 150 mm and thickness 10 mm was used to represent the contact area of loading at the top whereas a rigid base was available at the bottom of machine [4-7, 14, 17, 19-20]. The top loading plate of the unit cell has a spherical groove at the center to accommodate a steel ball in order to transfer the loads concentrically to the unit cell.

A compressive strength tests were performed on EPS geofoam unit cells with different heights and shapes as shown in Fig. 1. A unit cell was placed between two steel plates and loaded by the compressive testing machine with a constant deformation rate of 1.25 mm/min. Compressive loads corresponding to deformation are measured till failure of the specimen. The data was recorded by means of proving ring and dial gauges.

(a) circular shape (b) hexagonal shape (c) square shape

Fig. 1 EPS geofoam with different shapes and sizes

After preparation of a unit cell the core of the cell was filled with flyash to form a composite material. This composite material has a total area 100 cm^2. From this total area, the area occupied by the unit cell is about 36% and the area filled with flyash is 64%. The flyash was filled inside the core of the unit cell at its optimum moisture content and compacted in layers of 25 mm height. The amount of dry flyash required to fill the desired height was calculated first and compacted in 2, 2.5, 3 and 4 layers with respect to 50, 60, 75 and 100 mm height of unit cells respectively. The flyash was compacted inside the core of the unit cell by means of a specially fabricated rammer .The maximum dry density and optimum moisture content of flyash was found to be 1570 kg/m^3 and 15% respectively. The compaction effort yields a degree of compaction at 82% of the maximum dry density. By controlling the compaction effort a fairy uniform condition was maintained throughout the test program.

4 Results and Discussion

Fig 2 represents the stress-strain behavior of the unit cell flyash composite material with different heights of EPS geofoam having densities 14 kg/m^3 and 24 kg/m^3. It also gives an idea about the stiffness of the material tested. Higher failure compressive strength and stiffness is observed for less unit cell height. All the tested specimens of geofoam unit cell were failed between strain ranges of 7 to 10 %. The responses are observed to be non-linear for all the cases.

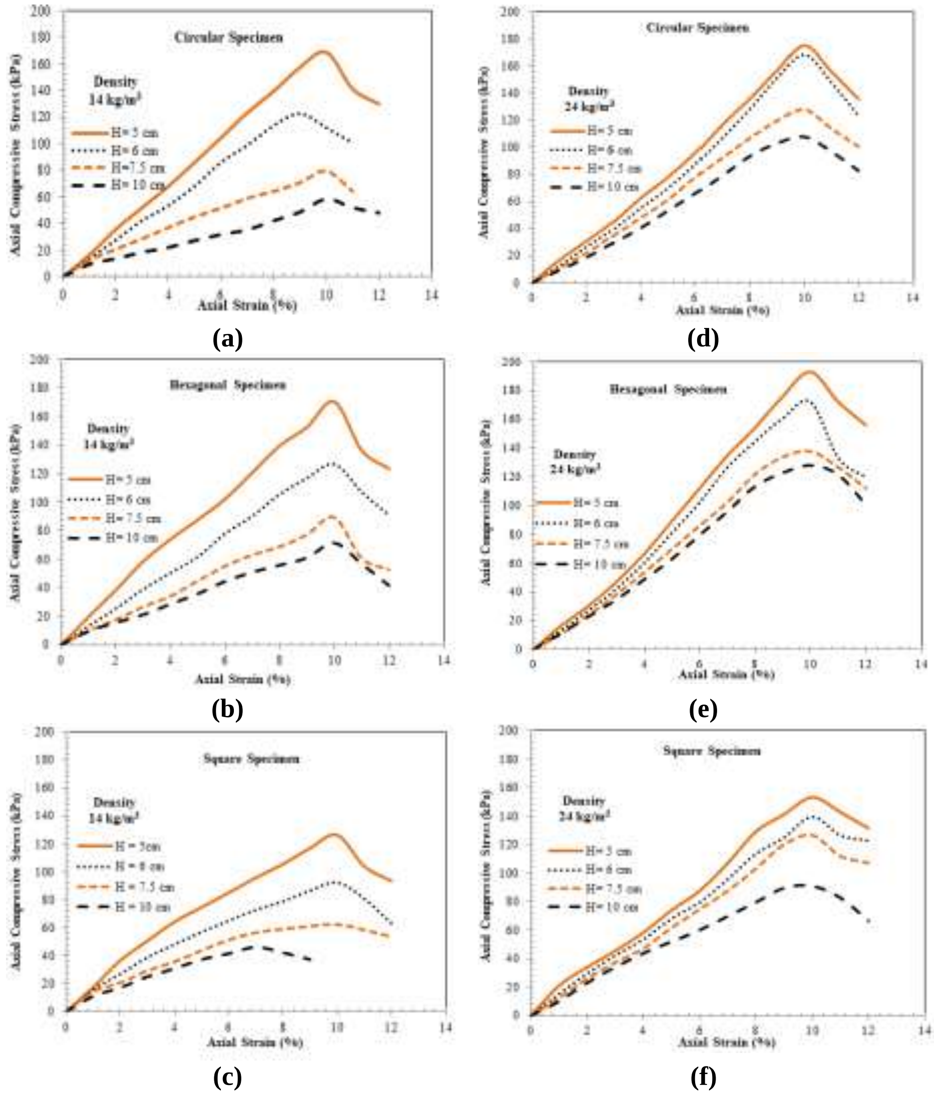


Fig. 2 Compression Strength Test Results for composite materials with geofoam densities 14 kg/m^3 (a, b, c) and 24 kg/m^3 (d, e, f)

From the test results, it is observed that the failure compressive strength of the composite material decreases with increase in the unit cell height. For a particular density, increase in the height of the unit cell from 50 to 75 mm exhibits considerable reduction in compressive strength compared to 75 to 100 mm height as seen from the Fig.3.

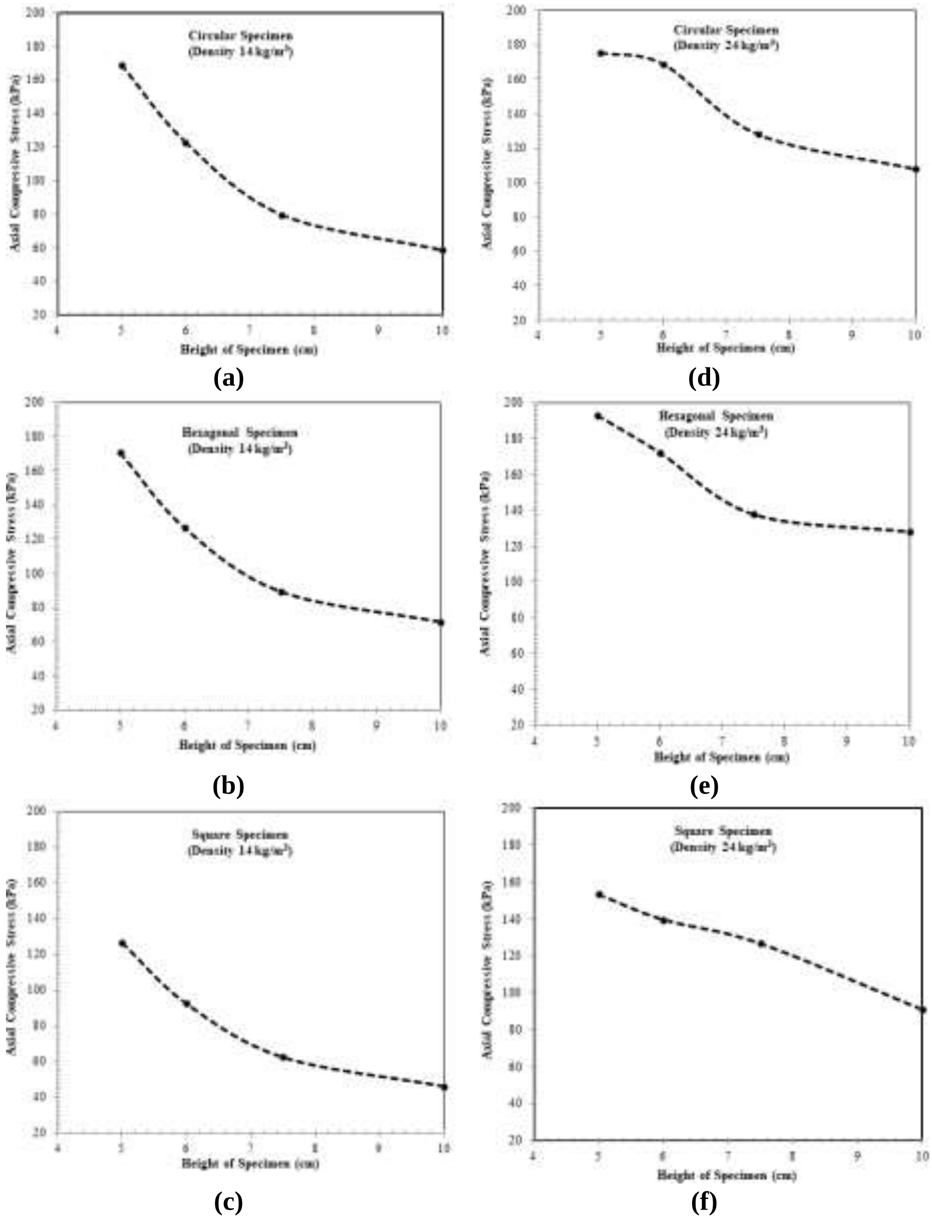
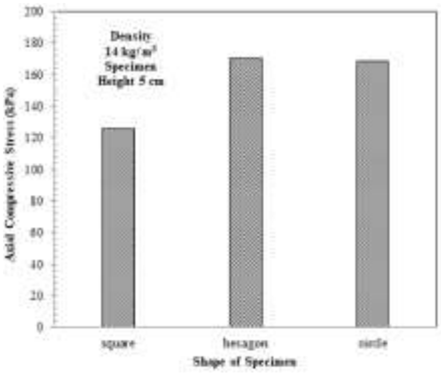
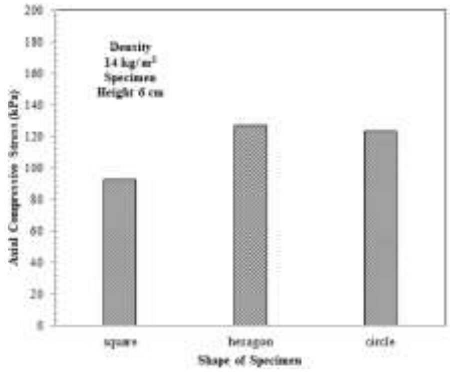


Fig. 3 Variation of axial compressive stress with height of geofoam specimens with geofoam densities 14 kg/m^3 (a, b, c) and 24 kg/m^3 (d, e, f)

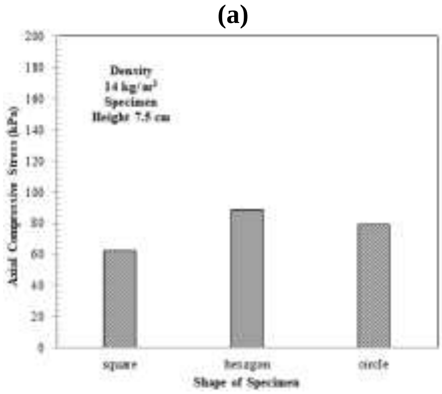
From Fig 4 it is clear that, failure compressive strength for hexagonal and circular specimen is relatively more than square specimens. With increase in the height of specimen, axial compressive stress decreases.


Density
14 kg/m³
Specimen
Height 5 cm
Axial Compressive Stress (kPa)
square
hexagon
circle
Shape of Specimen

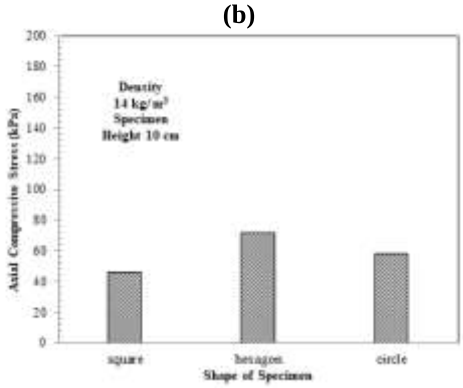
(a)


Density
14 kg/m³
Specimen
Height 6 cm
Axial Compressive Stress (kPa)
square
hexagon
circle
Shape of Specimen

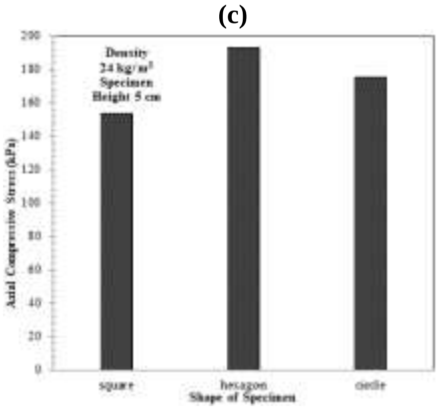
(b)


Density
14 kg/m³
Specimen
Height 7.5 cm
Axial Compressive Stress (kPa)
square
hexagon
circle
Shape of Specimen

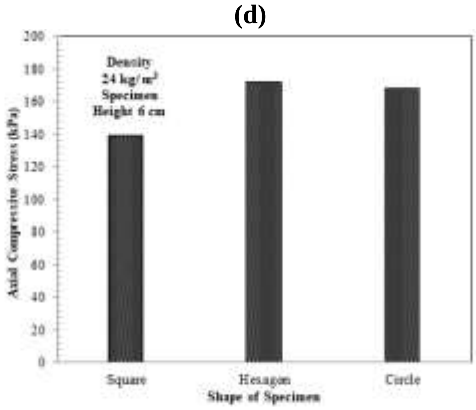
(c)


Density
14 kg/m³
Specimen
Height 10 cm
Axial Compressive Stress (kPa)
square
hexagon
circle
Shape of Specimen

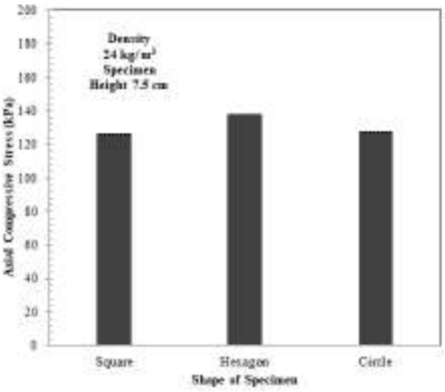
(d)


Density
24 kg/m³
Specimen
Height 5 cm
Axial Compressive Stress (kPa)
square
hexagon
circle
Shape of Specimen

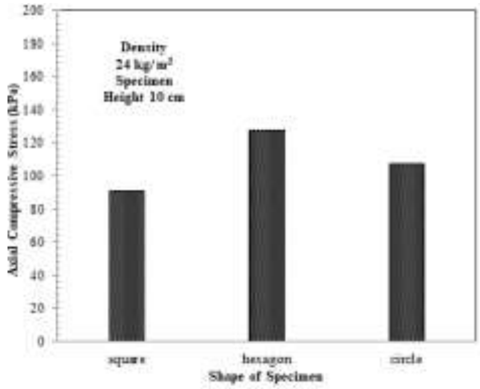
(e)


Density
24 kg/m³
Specimen
Height 6 cm
Axial Compressive Stress (kPa)
Square
Hexagon
Circle
Shape of Specimen

(f)



(g)



(h)

Fig. 4 Effect of shape of geofoam on compressive strength of composite materials with geofoam densities 14 kg/m^3 (a, b, c, d) and 24 kg/m^3 (e, f, g, h)

4.1 Failure patterns

For different unit cells, two types of failure were observed in the experimental investigation depending upon the height. A unit cell was failed all around the periphery of its geometry as shown in Fig. 5. It may be due to less height of the cell which carried considerable load and failed. Similar failure patterns were observed for all densities [4-7, 24-28]. But if the height of sample was increased the sample was failed from one of its side as it buckles. The failure patterns for the EPS geofoam unit cell are based on the crushing and buckling effect depending upon the height of the cell similar to short and long column. Unit cells with short height undergo crushing failure whereas the taller height exhibits bucking. Therefore, it can be said that the failure pattern in EPS geofoam unit cell changes from crushing to buckling with increase in height.

(a) Hexagonal shape

(b) Circular shape

(C) Square shape

Fig. 5 Failure patterns

5 Conclusions

Present study is an experimental work to witness the effects of EPS geofoam unit cell shapes and heights on the failure compressive strength of composite material. The compressive strength of EPS geofoam unit cell is decreased with increase in density of EPS geofoam as well as height which is similar to short and tall column. The nature of stress strain curves is found to be non-linear for all the cases. The failure pattern in EPS geofoam unit cell changes from crushing to buckling with increase in height. Based on the test observations following conclusions are made;

- The stress strain behavior found is non-linear.
- The failure compressive strength of EPS geofoam unit cell decreases with increase in the height of unit cell for a particular density
- The failure compressive strength of EPS geofoam unit cell is increased with increase in density of geofoam (EPS) for all the heights of unit cell
- The failure compressive strength depends upon the shape of unit cell. Hexagonal shape have a higher compressive strength as compared to circular shape and circular shape have higher compressive strength as compared to square shape
- The failure pattern in EPS geofoam unit cell changes from crushing to buckling with increase in height of unit cell.

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