Earth Pressure Reduction Studies on Covered Pipelines with Geofoam

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Abstract— India is currently investing heavily in pipelines. Given the high soil pressure in our country, it is important to ensure the soil pressure safety of underground pipelines. These facts have made the performance of buried and above-ground piping structures that are subject to fault and soil liquefaction an important subject of investigation. Pipelines are considered the most reliable, economical and efficient means of transporting water and other commercial liquids such as oil and gas. These piping systems are commonly used to transport water, sewage, oil, natural gas and other materials. They are often referred to as "lifelines" because they contain materials that are essential for life support and property maintenance. The ground pressure safety of underground pipelines has received great attention in recent years. Pipelines are important, large-scale lifeline systems that are exposed to a range of seismic hazards and soil conditions. Many buried pipelines in India run under high ground pressure and are therefore exposed to considerable buried pipelines. Pipelines running through strongly seismic zones should be designed so that they remain functional even after strong earthquake vibrations. Piping systems are commonly used to transport water, sewage, oil, natural gas, etc. over a large area and are exposed to a variety of seismic hazards and soil conditions. As a rule, pipelines are laid underground, primarily for aesthetic, safety-related, economic and ecological reasons.

Keywords: Earth Pressure Reduction, Geofoam, Pipelines

I. INTRODUCTION

Pipelines are considered the most reliable, economical and efficient means of transporting water and other commercial liquids such as oil and gas. These piping systems are commonly used to transport water, sewage, oil, natural gas and other materials. They are often referred to as "lifelines" because they contain materials that are essential for life support and property maintenance. The ground pressure safety of underground pipelines has received great attention in recent years. Pipelines are important, large-scale lifeline systems that are exposed to a range of seismic hazards and soil conditions. Many buried pipelines in India run under high ground pressure and are therefore exposed to considerable buried pipelines. Pipelines running through strongly seismic zones should be designed so that they remain functional even after strong earthquake vibrations. Piping systems are commonly used to transport water, sewage, oil, natural gas, etc. over a large area and are exposed to a variety of seismic hazards and soil conditions. As a rule, pipelines are laid underground, primarily for aesthetic, safety-related, economic and ecological reasons.

Gas and liquid fuel lines are usually welded at the joints to act as a continuous pipe. Pipes with rigid connections (that is, the strength and stiffness of the connections are higher than those of the pipe cover) are generally referred to as continuous pipes. On the other hand, water supply lines with mechanical connections are generally treated as segmented lines. These segmented pipes consist of pipe segments that are connected by relatively flexible connections. Modern pipes made of ductile steel with continuous butt seams at the connection points have good ductility. It was found that the overall performance of oil and gas pipeline systems was relatively good in previous earthquakes. However, catastrophic failures have occurred in many cases, particularly in areas with unstable soils. The failures were mainly caused by large permanent movements to the ground. A pipeline transmission system is a linear system that crosses a large geographical area and, therefore, soil conditions are subject to a variety of seismic hazards. Severe ruptures or distortions in the pipe are generally associated with relative movements caused by faults, landslides, liquefaction, loss of beds or differential movements in abrupt interfaces between rock and soil. The most catastrophic damages caused by failures and liquefaction are worth mentioning.

II. USE OF GEOFOAM

Geofoam has been recognized, in relation to its low unit weight, as an attractive alternative for sanitary landfills in special infrastructure works, for example, widened embankments, stirrups or bridges, retention works and buried flexible pipe fillings. Geofoam replacements were able to mitigate the vertical stresses imposed on underlying difficult soils or flexible service pipes, as well as reduce the lateral stresses loaded on the lateral floor structures. In practice, the geofoam also demonstrated favorable yields in the damping of mechanical impacts, for example, swelling of the expansive soil and seismic vibrations, as well as in the mitigation of thermal disturbances in the permafrost regions, the geofoam can be prefabricated expanded polystyrene or the mixture of floors and pearls of rejection EPS. Both need to be investigated with respect to measuring and modeling their stress-strain characteristics to evaluate the design and construction of the field. To date, research on EPS blocks can be reached through many sources.

III. NEED OF INVESTIGATION

Buried pipes are exposed due to ground pressure and live load. PCC materials are also used to reduce the pressure of the earth and are able to address these problems. PCCs have the property to transfer cargo directly into a buried pipe. Due to the PCC load after one year, the pipeline will have the opportunity to be exposed. Compared to the PCC material, Geofoam enjoys a number of benefits, such as better strength, load resistance, lighter weight, easier maneuvers on site and the ability to maintain similar or even better strength of the material.

IV. AIM AND OBJECTIVES OF THE PRESENT STUDY

The use of geofoam inclusions appears as an innovative approach to reduce ground pressures in buried pipes. Several studies focused on the potential efficiency of reducing load of geofoam inclusions, indicating that the reduction performance of geofoam inclusions depends on the characteristics of the mechanical characteristics of the fill and deformable materials.

The use of geofoam for buried pipe technology has grown since the last ten years because it improves durability, simplicity and increases the resistance and load capacity of the soil. Some ground pressure is produced in buried pipes, by using geofoam we can reduce this pressure.

V. SYSTEM DEVELOPMENT

A. Materials

1) Soil:

Soil can be defined as the unconsolidated material deposited naturally that covers the surface of the earth, whose chemical, physical and biological properties are capable of supporting the growth of plants. Soil is a product of natural decomposition forces and chemical and physical forces that act on native rocks, vegetation and animal matter for an extremely long period of time; in some cases literally thousands of years. The factors involved in the formation of natural soils are: (1) living matter such as plants, animals, microorganisms); (2) weather such as cold, heat, snow, rain, wind) (3) parental materials such as fineness of the particle size, as well as its chemical and mineralogical composition; (4) relief and (5) time. The soil is a habitat for plants. As such, the physical, chemical and biological properties of the soil affect the growth of plants. The physical properties of a soil largely determine the ways in which it can be used. The size, shape and arrangement of the primary soil particles are known as the physical properties of the soil. Other important physical properties focus on the size and shape of the spaces between particle arrays, called pore space, which has a direct effect on the movement of air and water, the ability of the soil to supply nutrients to plants and the amount of water available for the plant. The proportions of the four main components of soils can vary greatly from place to place. The amount of water and air in a soil can also fluctuate widely from season to season. However, the physical characteristics of the solid components, inorganic and organic particles, are essentially immutable. The chemical properties of soils are important because, together with their physical and biological properties, they regulate the supply of nutrients to the plant. Without these nutrients supplied by the soil or applied as inorganic fertilizers, organically by manure and other vegetative materials, plant growth would cease.

The sand used was dry beach sand from Mumbai, composed of rounded and sub-rounded particles. The soil is classified according to USCS, SM. The curvature coefficient is 1.17 and the uniformity coefficient is 1.99. The maximum vacuum ratio (e_{max}) is 0.943 and the minimum vacuum ratio (e_{min}) 0.691. The specific gravity is 2.61. The corresponding unit weights for 55%, 75% and 85% were 1446.7 Kg / m ^ 3, 1488.0Kg / m ^ 3 and 1510.41 Kg / m ^ 3 respectively. The internal friction angles determined by conducting direct shear tests on dry sand placed at 55%, 75% and 85% relative density were found at 32 °, 35 ° and 38 ° respectively.

Fig. 1: Soil

2) Black cotton:

The black cotton used was dry farmland, composed of rounded and sub-rounded particles. The soil is classified according to USCS, SM. The black cotton (clay) floor used to find the corresponding MDD and OMC as 100% clay. For 100% clay MDD and OMC is 1.56 and 18% respectively.

Fig. 2: black cotton

3) Geofoam:

Light fill solutions have been used in many civil engineering projects worldwide. In places with poor soil conditions, alternative lightweight construction fillers, such as expanded polystyrene geofoam (EPS), wood chips and debris can be used instead of conventional fillers. These materials are used as floor additives. It is known that the type, aspect ratio and content of the additives play an important role in the mechanical properties of the mixtures. Lightweight filler materials have a wide range of civil engineering applications worldwide. They can be used as fillers on soft clay sites to avoid excessive settlement; as filler for retaining walls and basements to reduce horizontal driving forces; as filler material to increase the safety factor for the slopes by reducing the driving forces; as seismic dampers to relieve seismic forces, and so on. Various types of lightweight fillings, such as expanded polystyrene block (EPS) geofoam EPS geofoam is produced from gasoline by expanding polystyrene particles and mixing them together. It is thermoplastic foam with closed pores and usually white. The expanded polystyrene (EPS) geofoam has now been used throughout the world as a notable substitute for light soil for a variety of geotechnical applications in the construction of soft terrain. The characterizations of EPS properties for the determination of design parameters have been based on laboratory tests of small samples. The use of expanded polystyrene (EPS) as a lightweight material is growing rapidly in the United States and elsewhere. Several geotechnical applications use geofoam. Among these are embankments, retaining walls, slope stabilization and bridge stirrups. Young's modulus values for geofoam are commonly determined by testing 0.05 m cube samples in accordance with ASTM-D-1621, EN826 or ISO-844, cylindrical samples 0.15 m in diameter 0.6 m high were used and compared Young's module for geofoam EPS derived from laboratory tests at values calculated from the test of the decreasing weight deflectometer. Geofoam used for the test is based on thickness and density. Geofoam is expanded polystyrene material. The corresponding thickness is 20 mm and a density of 16 Kg / m ^ 3. Geofoam is available in the market. Figure 3.3 shows the geofoam.

VI. Methodology

A. UTM:

The test is performed on the universal testing machine (UTM) .UTM is available at the university. With capacity of 1000 KN. In UTM compression, the tensile test, etc. can be performed. Available UTM is manufactured by Hydraulic and engg. Instruments, New Delhi (HEICO). Figure 3.4 shows the UTM.

B. Box:

The test configuration consists of a mild steel (MS) safe that is 498 mm long, 165 mm wide and 400 mm high (internally). Four handles are provided on the upper side to hold them. Figure 3.5 shows the mild steel case.

C. Transparent Glass:

The front wall of a model test package is formed with a 120 mm thick glass sheet that allows you to see the deformation and purpose of the image analysis.

D. Marker:

Before placing strips of polyethylene sheet, a rectangular grid of permanent markers was placed on the outer side of the glass sheet. Plastic markers are shaped like L.

E. Polythene:

The front walls were coated with a thin layer of white petroleum grease and 60 mm wide polyethylene sheets were placed to reduce the effects of limit friction.

F. Camera:

To view the front elevation of the model during the test, a digital camera is mounted together with the model test package.

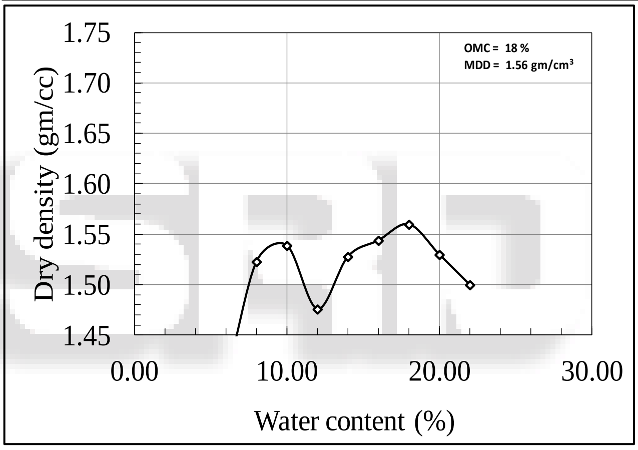
Fig. 3: Mild steel box

VII. Performance and Analyses

A. Standard Proctor test

Reading of Standard Proctor test for pure black cotton soil.

WATER CONTENT (IN %)	2	4	6	8	10	12	14	16	18	20	22
DRY DENSITY (IN gm/cc)	1.354	1.346	1.41	1.523	1.539	1.476	1.528	1.544	1.56	1.53	1.5

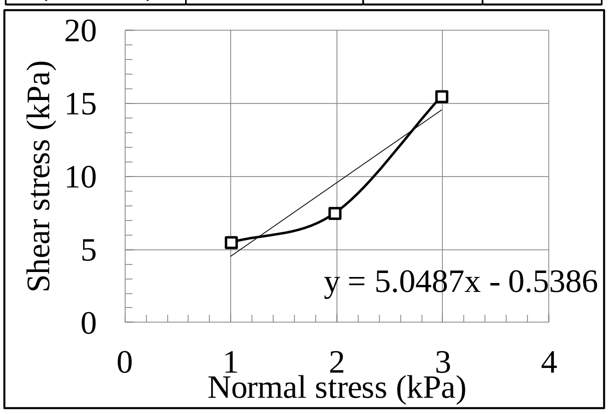


Graph A: Standard proctor test graph

B. Direct Shear Test

Direct shear test reading and graph for pure black cotton soil.

Shear stress (KN/mm2)	5.5	7.5	15.5
Normal Stress (KN/mm2)	1.000075	1.97835	2.9866



Graph B: Direct shear test graph

VIII. MODEL MAKING

A. *For Sand*

At the time of making the model, after placing strips of polyethylene sheets, a 20 mm thick base layer was placed at a relative density of 55% to represent a firm base. For each model, the desired number layers were placed one by one and dry sand was placed after each layer at a relative density of 55%. In order to track the movement, each layer in the L-shaped plastic marker box was glued to the layers of the model. A plastic marker leg was placed on the layer and another portion was applied to the white oil grease layer to facilitate movement. A plastic marker was placed on each layer with a separation of 20 mm from center to center. After the fifth layer, the HDPE tube is placed in the center of the box. The pipe was filled with clay to prevent sand from entering the pipe. After placing the pipe layer it was equal to the lower layer. The last step of model making was to place the strip load in the center of the box.

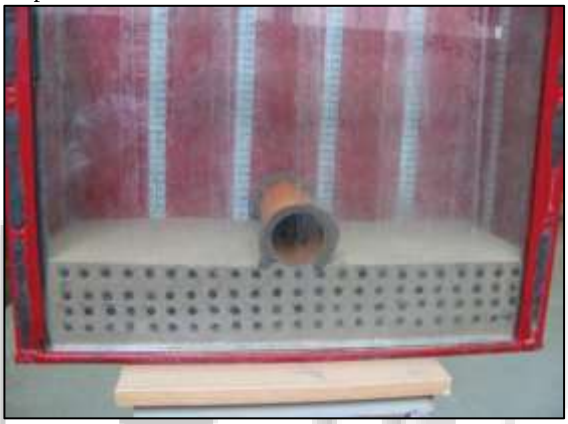


Fig. 4: Model making

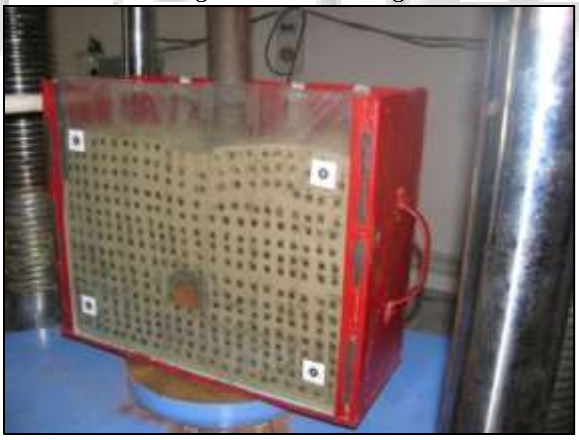


Fig. 5: Test setup for Sand

B. *For Black cotton*

At the time of making the model, after placing strips of polyethylene sheets, a base layer of 20 mm thick in MDD of 1.56 gm / cm ^ 2 and water content was placed in approximately 18% of the sample. For each model, the desired number layers were placed one by one and clay was placed after each layer at MDD 1.56 gm / cm ^ 2. In order to track the movement, each layer in the plastic shaped marker box of L stuck to the layers of the model. A plastic marker leg was placed on the layer and another portion was applied to the white oil grease layer to facilitate movement. A plastic marker was placed on each layer with a separation of 20 mm from center to center.

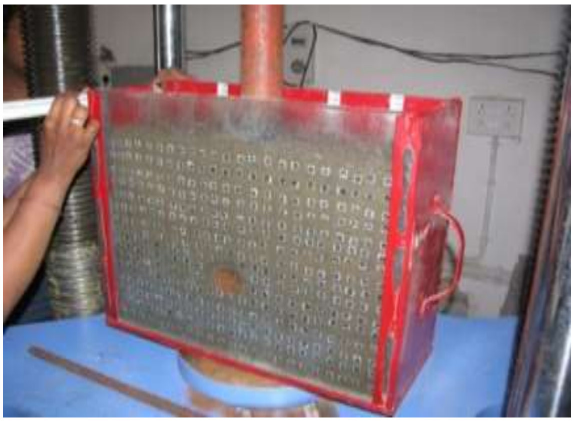


Fig. 6: Test setup for B.C.

C. *Effect of geofoam*

1) *Sand*

When geofoam is not used, the pressure is subjected directly to the HDPE pipe. And when geofoam is used, the pressure is distributed and the pressure is reduced in the HDPE pipe.

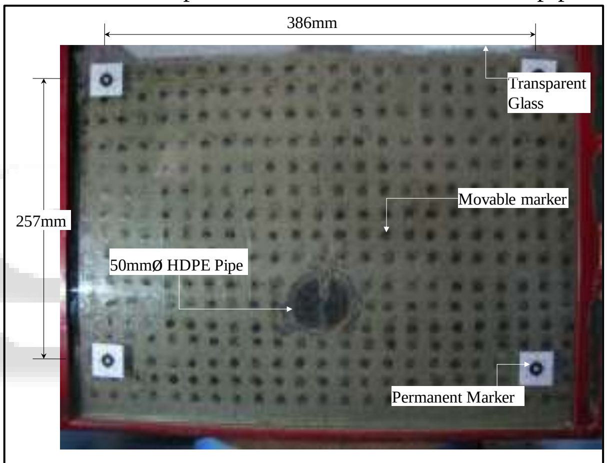


Fig:-Before applying load and without geofoam

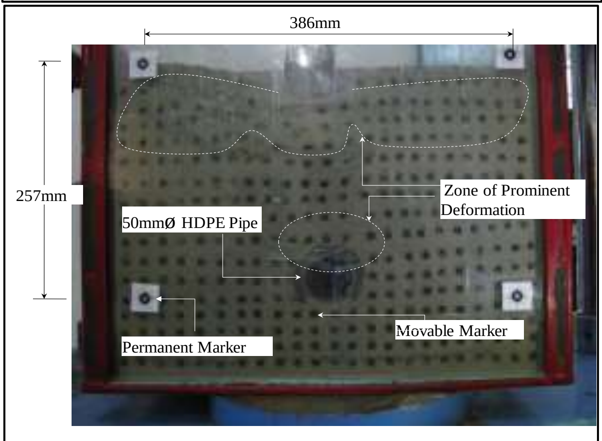


Fig:-After applying load and without geofoam

Fig. 7 & 8: Test package for sand without geofoam before and after load is applied.

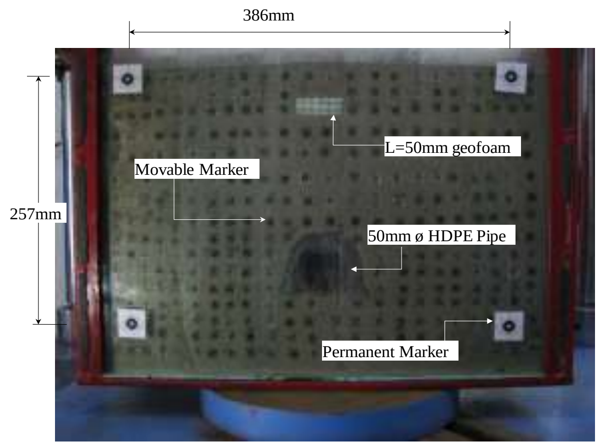


Fig:- Before applying load and with geofoam density(ρ)=8kg/m³

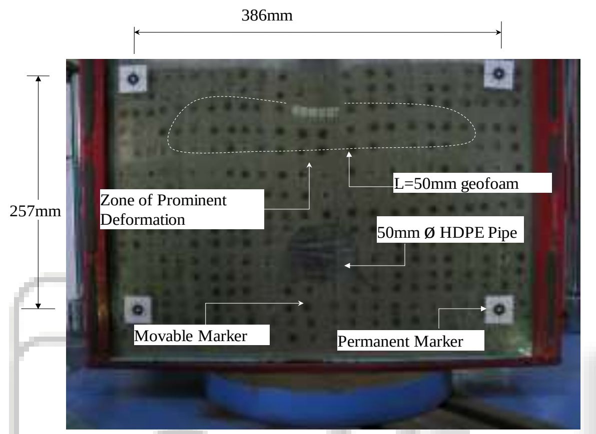
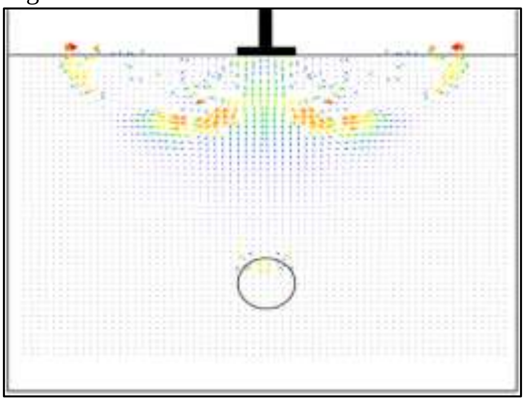


Fig:- After applying load and with geofoam density(ρ)=8kg/m³

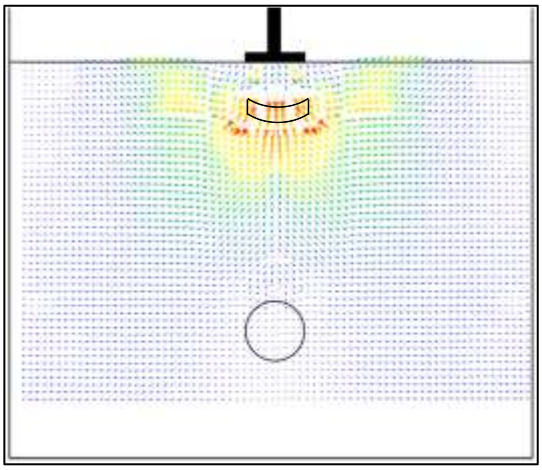
Fig. 9 & 10: Test package of with for sand geofoam Before and after load is applied

IX. RESULTS

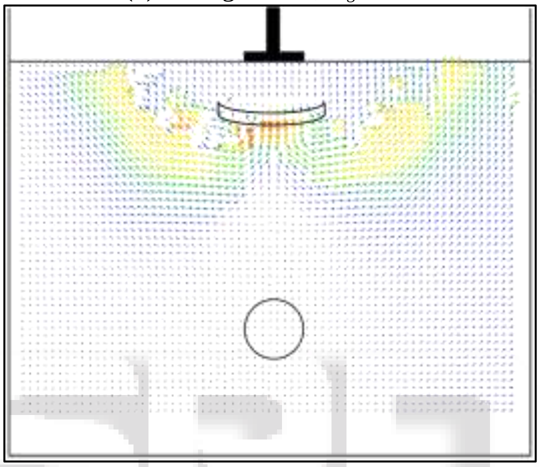
Image Analysis: - The image analysis was performed on the images obtained from the tests performed with the help of the open source software ImageJ. Displacements occurred at the top and around the pipe and the geofoam buffer measured using the advanced template matching complements and the PIV (Particle Image Velocimetry) analysis. Figure 6 shows the deformed profile of experimental models with and without geofoam.



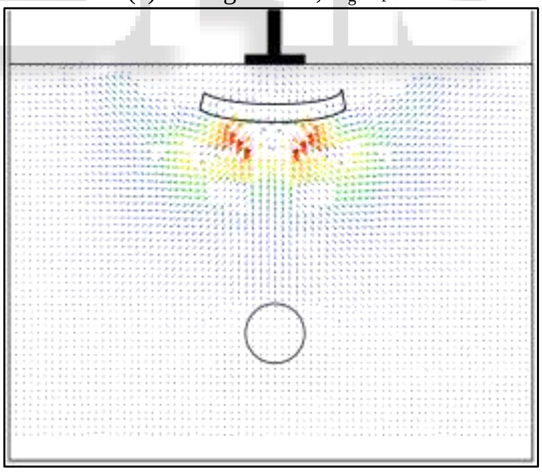
(a) Without geofoam



(b) With geofoam, $B_g/B_f=1$



(c) With geofoam, $B_g/B_f=2$



(d) With geofoam, $B_g/B_f=3$

Fig. 11: Displacement vectors for test models without and with geofoam ($\rho=8kg/m^3$)

The vectors in the figure are enlarged twice more than the original for a better visualization of the results. The general failure of Terzaghi's load capacity could be clearly observed when no geofoam inclusion was made. The deformations of the ground extend beyond the buried pipe and the plastic equilibrium zone moves away and forms a hoist on both sides of the shoe. When geofoam was placed below the shoe at a depth Bf, it was observed that these movements decreased with increasing geofoam width.

The inclusion of Geofoam provides a compressible bed under the shoe that is compressed according to the transferred load forming an inverted arc. Because of this, the load transfer deviates from the axial direction to the external diagonal directions. At the same time, most of the movements in the ground occur well above the buried pipe. This facilitates the improvement of the resistance to the cut of the ground and, therefore, transfers less loads in the buried pipe.

The deformations in the vertical direction were calculated from the image analysis for all model tests performed in the present study. It was observed that the deformations in the pipe are inversely proportional to the width of the geofoam and directly proportional to the density of the geofoam. Therefore, different densities are affecting deformation and distribution load. He noted that the geofoam density of 8 kg / m3 gave less distribution and load capacity than the densities of 16 kg / m3 and 24 kg / m3. In the vector diagram above, the arrows show the deformation (movement) on earth. Therefore, it is observed that when geofoam is placed in the pipe, then the ground pressure is distributed and because this life of the pipe increases.

X. Conclusions

Based on the observations made in the present study, the conclusions made are the following:

1) Geofoam as a compressible inclusion placed under the shoe provides a significant reduction in the load transferred in buried pipes.
2) The load on buried pipes is reduced as the density of geofoam inclusion decreases. Therefore, the transferred load could be minimized by decreasing the density of geofoam inclusion.
3) With the increase in geofoam width, the load reduction increases. This is mainly due to the arching of the soil on the pipe, as well as the wide distribution of deformations in the mass of the soil that is mobilized with the increase in the width of the geofoam foam.

Test legend	Geofoam width (mm)	Geofoam density (kg/m³)	Vertical deformation in pipe, Sp/Dp (m)	Load transferred on pipe (kN)
BP01	*N.A	*N.A	0.28	30
BP02	50	8	0.16	25
BP03	100		0.12	21
BP04	150		0.1	20
BP05	50	16	0.2	27
BP06	100		0.16	25
BP07	150		0.14	26
BP08	50	24	0.24	29
BP09	100		0.22	28
BP10	150		0.18	27
*Not applicable as test was performed without geofoam inclusion				

Table 1: Summary of the model tests performed in the present study

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