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Experimental Simulation for Load Reduction Techniques on Underground Utilities Using Geofoam

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Abstract

This paper investigates an experimental study on reducing stress acting on buried flexible pipes by using expanded polystyrene (EPS) geofoam techniques. An experimental model was carried out with dimensions depending on pipe diameter (D) and location, the used fill cover material was from sand and EPS blocks either embankment form, or within sand backfill as embedded layer. The pipe flexible is un-plasticized polyvinyl chloride (UPVC). A series of experiments have been carried out by using static surface loading on rectangular steel plate,where the load is distributed over the backfill. The behavior of sand backfill around the pipe was observed, and the displacement and strains of the pipe were measured.

The experimental results showed that the embedded layer of EPS geofoam block embedded in sand for different techniques reduced the deformation of flexible buried pipe, with high efficiency and low coast compared with EPS geofoam only. The results reveal that, the most effective methods that can reduce the stress on buried flexible pipe with low cost were EPS encasement block with head void method, and EPS block embraces the upper part of pipe method.

Keywords

buried flexible pipes; geofoam; a laboratory setup.

1. Introduction

Underground utilities are infrastructures such as conduits and buried pipelines systems used for transmitting or distributing water supply, gas, electricity, lights, storm drains; etc.. Underground utilities are expected to withstand induced stresses from dead and live loads on pipe . All these loads cause problems such as radial deformation, ring bending (crushing), axial extension or compression and longitudinal bending moment, these problems may lead to leakage or broken of pipe network (Ng, 1994).

The Expanded Polystyrene (EPS) geofoam was used as lightweight construction material goes back to 1972 at Oslo, Norway for the roadway project. This material was used as foam blocks in the USA in 1980s and Japanese constructed their first lightweight fill project at 1985 (NCHRP, 2004).

Because of the advantages of EPS as lightweight, low coast thermal resistance, vibration damping and compressible properties, it has been used with different techniques in many countries at last decades in Europe, United States, Canada and Japan for roadways, railways and covering underground utilities. Geofoam also used to solve many important engineering problems such as settlement, bearing capacity of weak layers, and slope stability problems (Stark et al., 2012 and Bartlett et al., 2015).

Vaslestad et al., (1993) investigated the EPS geofoam layer as imperfect ditch method above four rigid culverts had dimensions 1.6m diameter and 15m overburden high. The results showed that, the overburden ressure reduction at the crown was ranging from 50% to 75%.

Yoshizaka and Sakanoue (2003) investigated EPS Geofoam as a lightweight cover on pipe to reduce lateral force-displacement relationships for buried pipes. They found that, the EPS geofoam reduced the lateral soil-pipe forces by about 33 to 60%for pipe undergoing horizontal displacement.

Ahmed et al., (2013) studied the earth pressure interaction between the backfill and the wall of rigid pipe under static and cyclic loading conditions. The results investigated that the embedded EPS geofoam reduced the earth pressure on the rigid pipe.

This research studies by performing a series of laboratory experimental model tests, the stress and deformation of flexible UPVC buried pipes and the soil backfill behavior around it was observed under static surface loading. Different techniques using EPS geofoam with different densities as backfill material was evaluated to reduce stress on buried pipes, and minimize its deformation. The experimental results of all tested cases were compared to deduce the most effective backfill method are comparing for all cases.

2. Materials and Experimental Model

2.1. Materials

Expanded polystyrene EPS Geofoam has many types and shapes which depending on the usage case. EPS geofoam blocks are produced with two types: EPS15 & EPS30, the properties of EPS geofoam are listed in table (1). Sand material used in research was from The Eastern Desert of Egypt. The sample is passing on sieve No. 4 (4.76 mm), table (1) also shows the properties of used sand. The used un-plasticized polyvinyl chloride (UPVC) pipe is of 110mm diameter and 600mm long, with thickness of 4mm, the specification of UPVC pipe according to manufacture are shown in Table (1).

Table 1. properties of materials

Property	Sand	EPS 15	EPS 30	UPVC pipe
Unit Weight (kN/m3)	15.5	0.147	0.298	14
Modulus of elasticity E (kN/m2)	11000	3000	8000	2×106
void ratio (e)	0.73	-	-	-
Specific gravity (GS)	2.69	-	-	-
Relative density (Dr)	0.25	-	-	-
Shear parameters	Φ=32°	-	-	-
Poisson's ratio(ν)	0.30	0.09	0.17	0.4

2.2. Loading Frame and Steel Tank

A loading frame has dimensions of the loading frame are 1400mm long x 1200 mm height. The loading frame is fixed with steel tank as shown in figure (1). The dimensions of steel tank were approximately chosen to be more than the minimum rigid frame boundaries. The minimum rigid boundaries are 2D for vertical direction (where D is the pipe diameter) and 4D in horizontal directions (Kamel and Meguid, 2013). The overburden pressure above the pipe crest was 300mm (2.6D) from surface, and the rigid base of the tank was located at 315mm (2.8D) below the pipe invert. The lateral boundaries at a distance 615mm (5.5D) measured from its circumference, as shown in figure (1). The tank is approximately1380mm long, 1000mm height and 300mm wide, with a 10mm plexiglass face, the front side was reinforced horizontally using three 25mm steel box sections every 250 mm and vertically using two 100 mm steel U sections every 400 mm, and the rare side was from steel. The steel tank sides were painted to reduce the friction. A hole of 150mm in diameter was drilled in the front and a rear side, the whole size was larger than the diameter of the pipe to ensure that the pipe rests on sand directly, a rubber membrane was put at both ends of the pipe to prevent sand leakage during loading condition.

The compression load was applied using a hydraulic jack with load gauge operated by manual pump. Dial gauges were used to measure the vertical settlement of the surface plate and the pipe deformations. Electrical strain rosettes with gauge length of6 mm and gauge factor of 2.12 + 1 % were used to measure the strain at the outer face of the pipe, the stains were placed at crown and springline of the middle length section and connected to data logger.

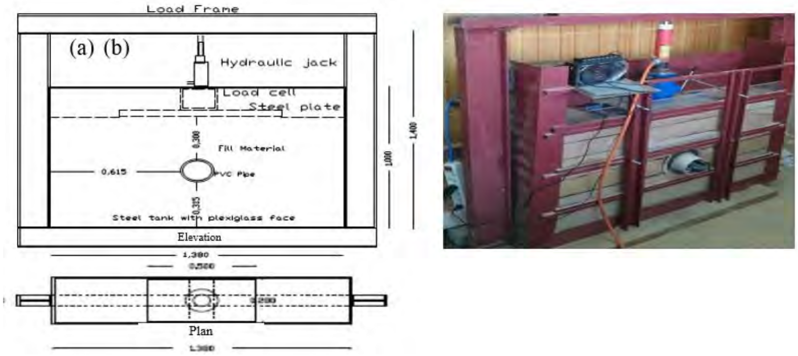


Figure 1. (a) The sketch diagram with dimensions of the model and (b)the loading frame and steeltank

3. Experimental Setup and Testing Procedures.

3.1. Overburden Sand Model

Three compacted layers of air dried sand with thickness of about 100mm for each layer were arranged from the base of tank to the lower level of the pipe. The UPVC pipe was placed in position crossing the tank faces from a hole of 150mm, and a rubber membrane was inserted around the pipe and bond with walls by silicon, the horizontal level of the pipe was checked. The sand placement was poured and compacted around the pipe from invert to the crown, another two thin layers of colored sand were prepared at invert and crest of the pipe. Black lines were drawn on the outer side of glassfiber plate parallel to colored sand layers. The final layer of sand was added to completely cover the pipe and to reach the height of 300mm above the pipe crown. Colored layer of sand was put at the top of the overburden layer, the black line was drawn on the outside of the fiber glass.

3.2. Overburden EPS Blocks Model

After removing the overburden layer of sand and reaching to the lower level of the steel tank; a bed of sand was prepared from the base of model tank to the lower level of the pipe, the new pipe was inserted and placed over the sand bed, then geofoam blocks with dimensions of 300 mm×300 mm×100 mm were arranged as overburden layer with depth of 300mm, as shown in figure (2).

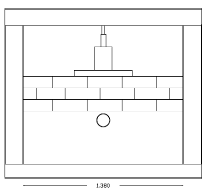


Figure 2. The experimental set up for the overburden EPS blocks model.

3.3. Embedded EPS Blocks over the Pipe (Imperfect Ditch) Model

A bed of sand was prepared from the base of model tank to the lower level of the pipe, then the sand was poured around the pipe and above by about until 20 mm and well compacted. A layer of EPS geofoam block was placedover sand with dimensions of 550mm×100mm, and then the sand was backfilled to reach a height of 300mm over pipe crown, as shown in figure (3)

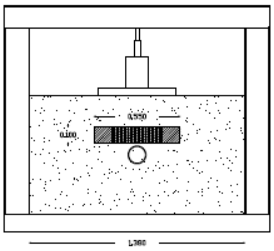


Figure 3. The experimental set up for the embedded EPS Block over the pipe model

3.4. Embedded EPS Block Embraces the Pipe upper Part Model

As in the previous model, a bed of sand was prepared from the base of model tank to the lower level of the pipe. The sand layer was completed to the lower mid-height of the pipe, then the upper mid-height was encased by preformed EPS geofoam block with dimensions of 330mm×165mm (3D*1.5D). The sand fill layer was completed to reach a height of 300mm over pipe crown, as shown in figure (4).

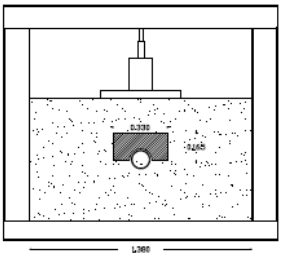


Figure 4. The experimental set pipe encased with embedded EPS block model

3.5. Pipe with Embedded EPS Encasement Blocks Model

A bed of sand was prepared from the base of model tank to the lower level of the pipe, then EPS geofoam blocks with dimensions 165mm height ×100 width were put at the both sides of the pipe, and covered by EPS beam block with dimensions 330 mm×165mm (2D*1.5D). The sand fill layer was completed to reach a height of 300 mm over pipe crown, as shown in figure (5).

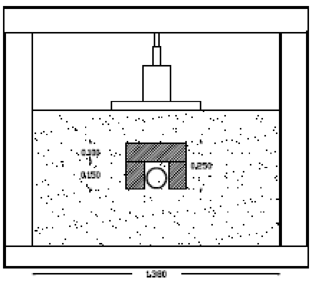


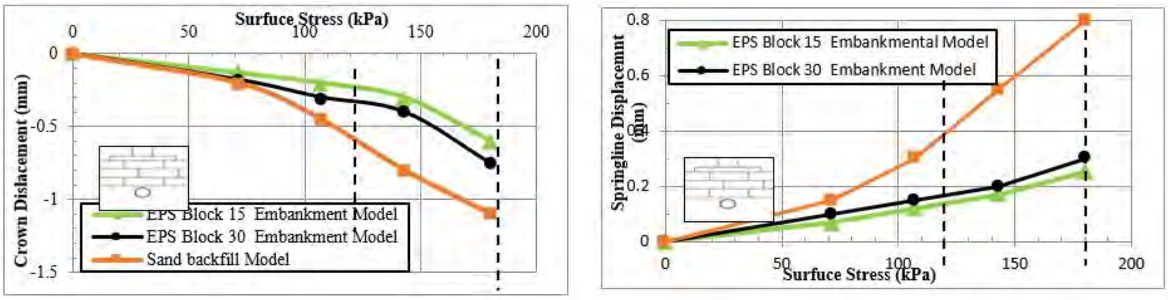
Figure 5. The experimental set up in case of pipe inside embedded EPS blocks culvert model

3.6. Testing Procedures

A load frame was used to transfer the load from hydraulic jack into a load cell which placed above a mild steel plate of size 500 mm x 280 mm x 30 mm to transmit the load uniformly to the sand, EPS geofoam blocks and buried pipe. The surface stress is based on the AASHTO HS-20 truck loads which transmit stress with impact factor 86kPa to buried pipe at depth 305mm. The rate of loading for all the experiments was constant.

4. Behavior of Buried Pipe in Different Backfill Models

4.1. Overburden EPS Blocks Model



(a) Vertical deformation (b) Horizontal deformation

Figure 6. Deformation of UPVC buried pipe under loading in case of EPS blocks (Embankment) model

Figure (6) shows the maximum horizontal and vertical displacement curves of pipe in case of sand backfill, the crown and the springline displacement behavior started linear with surface stress until it reaches the value of 71.5 kPa, then the behavior became nonlinear. On the other hand, the stress-displacement relationship of the overburden EPS blocks shows to be linear-relationship up a stress of about 180 kPa (nearly one and half the maximum linear load of sand backfill), under that load the reduction in pipe vertical deformation due to use EPS 15 and EPS 30 is about 46% and 36% respectively. While the reduction in the pipe horizontal deformation due to use EPS 15 and EPS 30 is about 70% and 57% respectively. It is worth noting that, EPS with less density partially release the applied by a degree little more than the denser one.

4.2. Embedded EPS Blocks over the Pipe (Imperfect Ditch) Model

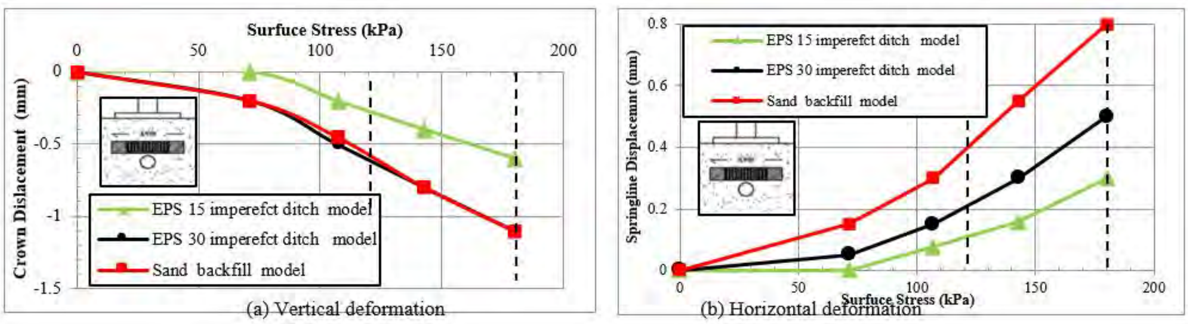
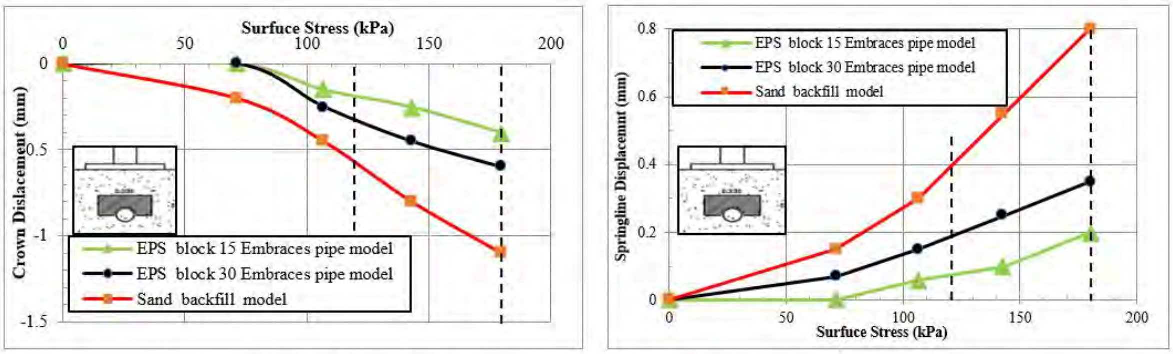


Figure 7. Deformationof UPVC buried pipe under embedded EPS blocks (Imperfect Ditch) model

Figure (7) shows that the maximum horizontal and vertical displacement curves of pipe in case of imperfect ditch method, for EPS30the crown and the springline displacement behavior started linear with surface stress until it reaches the value of 71.5 kPa, then the behavior became nonlinear. While in case of EPS 15 the crown and the springline displacement behavior started after 71.5kPa with linear behavior for crown and springline. Under the design surface stress 180kPa the reduction in pipe vertical deformation due to use EPS 15 and EPS 30 is about

60% and 0% respectively. While the reduction in the pipe horizontal deformation due to use EPS 15 and EPS 30 is about 50% and 37% respectively. It is worth noting that, EPS with less density partially release the applied by a degree little more than the denser one.

4.3. Embedded EPS Block Embraces the Pipe upper Part Model



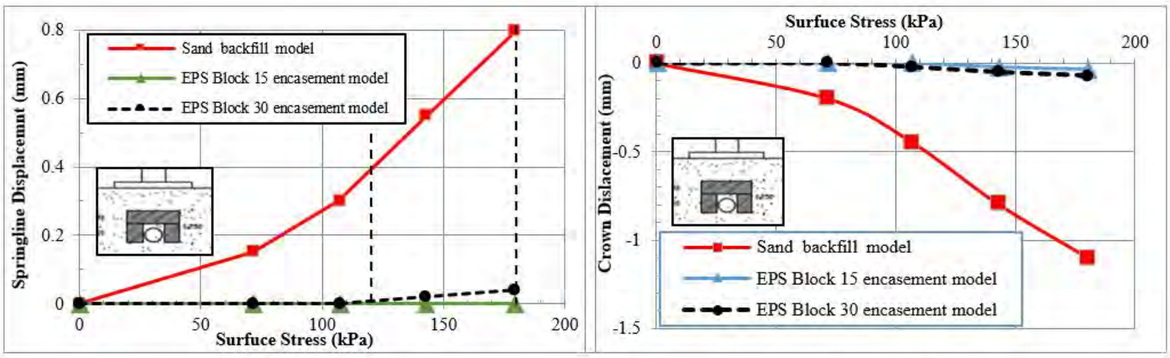
(a) Vertical deformation (b) Horizontal deformation

Figure 8. Deformation of UPVC buried pipe under Embedded EPS blocks embraces thepipe upper part model

Figure (8) shows that maximum horizontal and vertical displacement curves of pipe in case of embedded EPS blocks embraces the pipe upper part model, Under the design surface stress 180kPa the reduction in pipe vertical deformation due to use EPS 15 and EPS 30 is about 65% and 45% % respectively. While the reduction in the pipe horizontal deformation due to use EPS 15 and EPS 30 is about 75% and 55% respectively.

4.4. Embedded EPS Encasement Blocks Model

Figure (9) illustrates that maximum horizontal and vertical displacement curves of pipe in case of embedded EPS encasement blocks model, the crown and the springline displacement behavior started linear after surface stress107.5 kPa until it reaches the value of maximum surface stress180 kPa. Under the design surface stress 180kPa the reduction in pipe vertical deformation due to use EPS 15 and EPS 30 is about 95% and 95% % respectively. While the reduction in the pipe horizontal deformation due to use EPS 15 and EPS 30 is about 99% and 95% respectively.



(a) Vertical deformation (b) Horizontal deformation

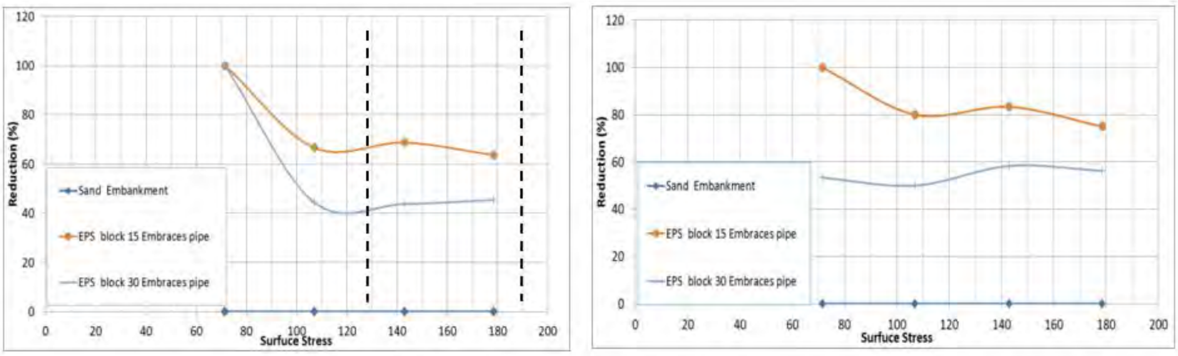
Figure 9. Deformation of UPVC buried pipe under embedded EPS encasement blocks model

These figures show that, the most effective method which reduce the surface stress and minimize the pipe deformations are EPS block embraces upper pipe method and EPS encasement block method. The EPS embankment method reduces the surface stress and the pipe deformations with high cost compared with EPS embraces and encasement methods which get the higher results with low cast. The imperfect ditch is not effective method in case of EPS30 because of small compressibility as it transfer the stress to the buried pipe, also EPS15 imperfect ditchmethod has not get good results although it has high compressibility. EPS15 is more effective than EPS30 at the same backfill method, due to its higher compressibility with lesser stress transfers to the buried pipe.

4.5. The Reduction Percentage of UPVC Buried Pipe in case of Optimum Backfill Models

4.5.1. **The Reduction Percentage in case of EPS Embraces Upper Pipe Model**

Figure 10(a) shows the reduction percentage of EPS block embraces upper pipe method at the crown, for EPS15 the reduction percentage is 100% at surface stress 70kPa and then it is decrease gradually to be 70% at surface stress 107kPa and 65% at maximum surface stress 180kPa, while EPS 30 reduction percentage at crown is 100% at surface stress71.5kPa and then it is decrease gradually to be 45% at 107kPa and finally the percentage is 45% at maximum surface stress. Figure 11(b) shows the reduction percentage of the pipe springline, in case of EPS 15 the reduction factor is 100% at surface stress 71.5kPa then it is decrease gradually to be 80% at 107kPa and finally reach to 75% at maximum surface stress, the EPS 30 reduction factor is 50% at start and it is increase gradually to be 55% at maximum surface stress.

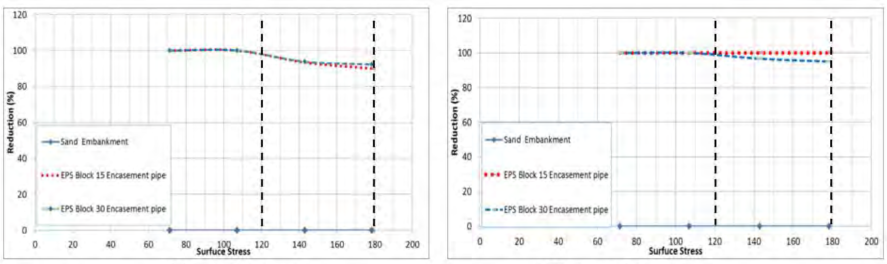


(a) Vertical Reduction (b) Horizontal Reduction

Figure 10. The reduction percentage of UPVC buried pipe incase of EPS embraces upper pipemethods.

4.5.2. The Reduction Percentage of UPVC buried pipe in case of EPS Encasement Pipe Model

Figure 11 (a) illustrates that the crown reduction percentage of EPS encasement block method, in case of EPS15 reduction percentage is 100% at surface stress 71.5kPa and 107kPa then it is decrease gradually to be 95% at maximum surface stress, in case of EPS 30 the crown reduction percentage is 100% at stress 71.5kPa and it is decrease gradually to be around 95% at maximum surface stress. Figure 11 (b) illustrates the springline reduction factor, in case of EPS15 the initial reduction factor is 100% at surface stress 71.5kPa reduced to 99% at maximum surface stress, in case of EPS 30 reduction factor is 100% at stress 71.5 kPa and reduced to 95% at maximum surface stress.



(a) Vertical deformation (b) Horizontal deformation

Figure 11. The reduction percentage of UPVC buried pipe in case of EPS encasement pipe methods.

4.6. The Strain Behavior of UPVC Buried Pipe in case of Different Models.

Figure (14) shows the diametral stress-strain relationship of buried pipe diameter at crown in case of different backfill methods. The results shown in figure indicate that all curves started with linear trend until the surface stress reaches the value of 71.5kPa then it changed to be a nonlinear except for the EPS encasement cover method which have a linear trend. The EPS 30 and EPS 15 embankment reduce the crown strain of the pipe by about 30% and 45%, respectively at maximum surface stress. The imperfect ditch method from EPS 30 has no effect on reducing crown strain, but the EPS 15 reduces the crown strain by about 45%at maximum surface stress. The EPS 30 and EPS 15 block embraces upper part of pipe method get the crown strain of the pipe by about 60% and 64%, respectively at maximum surface stress. EPS 30 and EPS 15 encasement block reduced the crown strain by about 93% and 95%, respectively at maximum surface stress.

Figure (15) shows the diametral stress-strain relationship of buried pipe diameter springline in case of different backfill methods. The results shown in figure indicate that all curves started with linear trend until the surface stress reach the value of 71.5kPa then the trend changed to be a nonlinear except EPS casement cover method and EPS embraces upper pipe which have a linear trend. EPS 30 and EPS 15 embankment method reduce the springline strain by about 56% and 68%, respectively. The imperfect ditch from EPS 30 and EPS 15 block reduce the springline strain by about 40% and 50%, respectively. EPS 30 and EPS 15 block embraces upper part of pipe method get the springline strain by about 81 and 86%, respectively. EPS 30 and EPS 15 encasement block reduced the springline strain by about 100%.

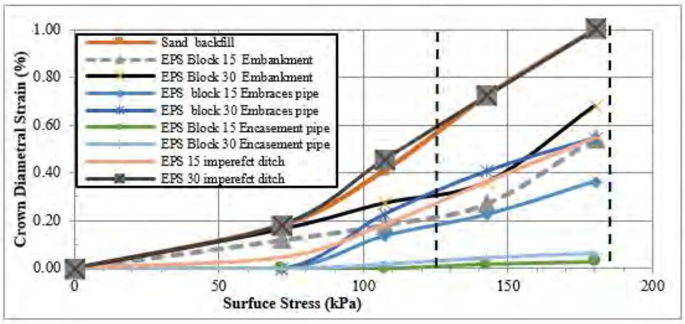


Figure 12. Crown diametral strain of UPVC buried pipe in case of different backfill models.

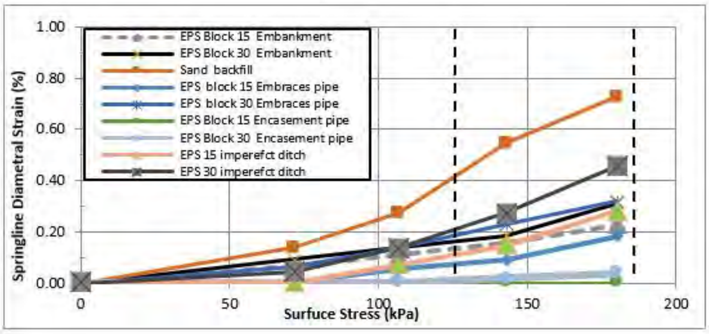


Figure 13. Springline diametral strain of UPVC buried pipe in case of different backfill models.

5. Conclusions

This research investigated the effect of EPS geofoam techniques to reduce the earth pressure on flexible buried pipes. Four techniques of EPS geofoam as a backfill were applied: (a) Embankment, (b) Imperfect ditch, (c) EPS block embraces the upper part pipe, and (d) EPS encasement block with head void. These systems of EPS geofoam defined as cover or as backfill system. A laboratory model was designed to set up backfill of height 300mm in rigid box over flexible pipe and the surface pressure was applied over the steel plate, the pipe has horizontal and vertical dial gauges. Two types of EPS with different densities were used. From this study the following conclusions were drawn:

1.The results show that the different methods of EPS Geofoam EPS 30 and EPS 15 reduce the earth pressure on flexible buried pipes and the displacement and stress of it with percentage depending on backfill method and loads type. So, these methods protect buried pipes.

2.The EPS geofoam embankment method reduced the vertical and horizontal deformations by about 36% and 40%, respectively for EPS 30, while for EPS 15 the reduction was higher with about 65% and 75%.

3.The EPS encasement block with head void method minimized the vertical and horizontal deformations by about 98 and 99%, respectively and by about 95 and 99% for EPS 15.

4.The imperfect ditch method from EPS 30 reduced the vertical and horizontal deformations by about 0 and 37%, respectively, while for EPS15 the vertical and horizontal deformations reduced by about 45 and 60%, respectively. The imperfect ditch method is not recommended in case of the backfill height300mm and the pipe is flexible.

5. The encasement with head void was the most effective method which reduces the stress over buried flexible pipe, followed by the EPS block embraces the upper pipe method.

6. References

1. Ahmed MR, Meguid MA, Whalen J. Laboratory Measurement of the Load Reduction on Buried Structures Overlain by EPS Geofoam. GeoMontreal Conference, Montreal, Quebec, 2013.p.1-10.

2. American Lifelines Alliance. Gideline for the Designe Buried Steel Pipe. American Sociaty of Civil Engineering ASCE, July 2001.

3. Bartlett S F, Lingwall B N, Vaslestad J. Methods of protecting buried pipelines and culverts in transportation infrastructure using EPS geofoam. Geotextiles and Geomembranes. June - 2015, pp1-12.

4. Ilamparuthi K, Rajkumar R. Experimental Study on the Behaviour of Buried Flexible Plastic Pipe. EJGE Journal, Vol. 13, Bund C. 2008, p.1- 10.

5. Kamel S, Meguid MA. Investigating The Effects of Local Contact Loss on the Earth Pressure Distribution on Rigid Pipes. Geotechnical and Geological Engineering 31(1), 2013. P.199–212.

6. National Cooperative Highway Research Program NCHRP. Geofoam Applications in the Design and Construction of Highway Embankments. Web Document 65 (Project 24-11) Stark, T. D., Arellano, D., Horvath, J. S. and Leshchinsky, D., Scarsdale, New York, 2004.

7. Ng P C F. Behaviour of Buried Pipelines Subjected to External Loading. Thesis submitted to the University of Sheffield for the Degree of Doctor of Philosophy, 1994.

8. Yoshizaka K, and Sakanoue T. Experimental study on soil-pipeline interaction using EPS backfill.Pipelines 2003.Copyright ASCE 2004.P. 1126-1134.

9. Stark TD, Bartlett SF, Arellano D. Expanded Polystyrene (EPS) Geofoam Applications and Technical Data. The EPS Industry Alliance, 1298 Cronson Blvd ., Suite 201, Crofton, MD 21114, 2012, p.1-36.

10. Vaslestad J, Johansen T H, Holm W. Load reduction on rigid culverts beneath high fills: Longterm behaviour. Transportation Research Record 1415, Norwegian Road Research Laboratory, Public Road Research Administration, 1993. P.58-68.