

Experimental and Numerical Studies on Mechanical Behavior of Buried Pipelines

Submitted in partial fulfillment of the requirements for the award of
Master of Engineering degree in Structural Engineering

by

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**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

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MAY - 2022



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DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE

CERTIFICATE

This is to certify that this Project Report is the bonafide work of **BINSON CHALISSERY JOHNSON (40380004)** who carried out the project entitled "**Experimental and Numerical Studies on Mechanical Behavior of Buried Pipelines**" under my supervision from November 2021 to May 2022.

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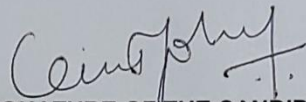
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DECLARATION

I **BINSON CHALISSERY JOHNSON** (Reg. No. 40380004) hereby declare that the Project Report entitled "**Experimental and Numerical Studies on Mechanical Behavior of Buried Pipelines**" done by me under the guidance of **Dr.R.NIRMALA**, is submitted in partial fulfillment of the requirements for the award of Master of Engineering degree in Structural Engineering.

DATE: 11-06-2022

PLACE: CHENNAI


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ABSTRACT

Buried pipes are commonly used for water distribution and drainage, but can also be used for petroleum, liquefied natural gas, coal sludge, mining tailing, etc. The contrast between rigid (reinforced concrete, vitrified clay, ductile cast iron) pipes and flexible (steel, UPVC, aluminium, fiberglass, high density polyethylene) pipes is subtle but important. The design of the flexible pipe is determined by its deflection or buckling. UPVC pipes are preferred for long-term chemical stability and cost-effectiveness due to their light weight and long service life.

The purpose of the study is the load-deformation behaviour of buried pipes and the stress variation of the entire pipe cross section under static load, and the effects of embedding depth and backfill density on pipe deformation and stress, and the deformation behaviour of buried pipes. Is to investigate. If the soil is covered with geogrid reinforcement, it will be reinforced and the load capacity of the pipe will be evaluated.

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LIST OF ABBREVIATIONS

HDPE	HIGH-DENSITY POLYETHYLENE
UPVC	UNPLASTICIZED POLYVINYL CHLORIDE
AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
MS	MILD STEEL
PVC	POLYVINYL CHLORIDE
LVDT	LINEAR VARIABLE DIFFERENTIAL TRANSFORMER
CADD	COMPUTER AIDED DESIGN AND DRAFTING

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INTRODUCTION

1.1 GENERAL

Pipelines play an important role in today's urban infrastructure. Landfill pipelines are most commonly used for water supply and drainage, but they can also be used to transport energy and mineral resources such as petroleum, liquefied natural gas, coal slurry, and tailings. Long-distance pipelines have also been proposed in water resource management and agricultural operations. Pipes used for these purposes can be rigid or soft, although the distinction between the two is blurred. Rigid pipes include reinforced concrete, vitrified clay and ductile iron. The rigid tube design is dictated by the yield strength of the material. The hose can be made of steel, PVC, aluminum, fiberglass or HDPE (high-density polyethylene) (HDPE). Elastic deflection or warping is used to control the design of the hose. Elastic deflection or warping is used to control the design of the hose.

Cast iron pipes have been widely employed to build water distribution systems in North America since the early twentieth century, while concrete pipes have been used to build sewer and drainage systems. These traditional pipes have an average lifespan of 50-70 years. As a result, most cities infrastructures are nearing the end of their design life. Furthermore, towns must cope with the expansion of their systems in order to keep up with population increase. Pipelines must be replaced or installed in order to replace or install new pipelines. New material kinds have been introduced as a result of today's technology, providing good alternatives and, Better goods in many circumstances. The soil pipe interaction between surrounding soil and the pipe determines the structural performance of buried pipe. Design concerns relating to structural performance and service life are becoming increasingly relevant as subterranean pipes are used in more applications.

1.2 UPVC PIPES

Unplasticized polyvinyl chloride, often known as rigid PVC pipe, is referred to as UPVC. The word rigid does not describe the structure of the object; rather, it identifies a quality that is self-explanatory. Pipes and fittings made of UPVC. Some of the qualities of UPVC pipes enable it to be put to good use. Below are some of its most prevalent characteristics.

1.2.1 Features of UPVC pipes

- **Low thermal conductivity**

This allows fluids to be delivered while maintaining a constant temperature. It also prevents pipes from sweating outwards when fluids at extremely low temperatures travel through them.

- **Electrical resistance**

The resistivity of UPVC is larger than 10^{14} Ohm.cm, thus it has excellent insulating characteristics. Earthing cannot be done with UPVC pipes.

- **Hydraulic resistance and flow characteristics**

Due to the smooth inner surface, UPVC pipes allow more water to flow than conventional pipes of the same size. The Hazen Williams constant for flow in UPVC pipes is about 150, which is higher than the Hazen Williams constant for traditional pipes and remains constant throughout the service life..

- **Chemical resistance**

The majority of acids, alkalis, organic compounds, fats, and oils have no effect on UPVC. Most chemicals don't corrode them, which makes them important for modern uses in a variety of industries.

- **Fire resistance**

These materials are naturally self-extinguishing and do not sustain combustion. Only the area of the pipes directly beneath the flame is scorched, and the fire does not spread.

- **Flexibility**

Because UPVC is a thermoplastic material, it can endure deformation in shape caused by earth movements.

1.3 TECHNICAL INFORMATION OF UPVC

Pipes and fittings made of UPVC (unplasticized polyvinylchloride) have good resistance to harsh conditions that arise naturally and as a result of industrial activities. They can withstand practically every sort of corrosion, whether chemical or electrochemical. Galvanic and electrochemical effects do not occur in UPVC pipes since it is a nonconductor. Pipes and fittings made of UPVC are frequently used in the following situations: Both main and supply lines are required for drinking water pipe distribution systems. Sewer and drainage pipe networks The substance utilised is completely resistant to all sorts of metallic corrosion due to its nonmetallic character.

UPVC pipes will not be harmed by aggressive water arising from high sulphate soils or low hardness water. As a result, our pipes are resistant to a wide range of industrial fluids and chemicals, providing a long-term benefit in system life and manufacturing costs. Please do not hesitate to contact Interplast for additional information about UPVC's chemical resistance. We will notify you of the best pipe solution available. UPVC pipes are neutral to all conveyed fluids since they are constructed of a tasteless and odourless material. UPVC is a chemically inert material that is commonly used to convey liquids intended for human use. UPVC pipes feature a low pressure drop due to their mirror-smooth internal surface. There is also no dirt build-up within, which is a significant benefit in sewer construction. Direct sunshine, wind, or rain have no effect on the physical qualities of uPVC pipes. The tube should be maintained out of direct sunlight to minimise surface discoloration caused by extended exposure to direct sunlight. PVC that is rigid is not a flame conductor. The flame cannot go through the uPVC pipe in the case of a fire. As a result, when employed in electrical systems, both in households and in business, they provide improved safety. Pipes made of uPVC are lightweight. Their specific gravity of 1.43 is one-fifth that of steel pipes.

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL

Many experiments and theoretical studies have been carried out to investigate the effects of hoses under different loading circumstances, soil conditions, burial depths, backfill cover and the use of reinforcing materials. different geology. The literature on these two strategies has been reviewed and summarized in the following sections.

2.2 LITERATURE REVIEW

Mir Mohammed Hoosseini (2000) constructed a physical model of the buried pipe trench scenario after conducting an experimental examination of the behaviour of buried pipes under cyclic loading conditions. A medium silica sand soil trench was used to place the steel flexible model pipes. The trench was produced inside the testing tank using a raining technique at three distinct relative densities. The depth of the pipes in the trench was changed, and cyclic loads of varied amplitudes were applied to the trench surface both centrally and eccentrically. Throughout the experimental investigation, the system's deflection behaviour and failure mechanism were shown to be substantially influenced by soil density, embedment depth, load amplitude, and load eccentricity. Eventually, when the embedding depth exceeded $2D$, the failure occurred simply because the loading plate subsided excessively, without serious damage to the pipe, even under high repetitive loads on the test area. However, in relatively soft soils, regardless of immersion depth, the system is primarily the first system due to excessive loads to sag, local buckling combined with weak contact or significant deflection when drive. In a few cycles, even small periodic loads failed, regardless of immersion depth, improper interweaving of particles and special placement of soil fabrics Therefore, leaving The soil around underground pipelines can cause serious damage to pipelines subjected to seismic loads.

Madaswamy Arokiasamy (2006) conducted field tests on large caliber HDPE, PVC, and metal pipes that load road vehicles. Numerical simulations were performed using a finite element approach to estimate the reaction of the pipe soil system under traffic loads. Field test data were compared with the ground pressure around and above the pipe, the cross-sectional profile of the deformed pipe, and the predicted response of the pipe deflection. Field test results have shown that embedded flexible

pipes embedded in highly compressed sloping sand containing silt work well without obvious joint openings or structural loads. The 5% deflection limit defined by AASHTO has been determined to be reasonable for installing flexible pipes during construction in shallow burial conditions. A 2% vertical deflection limit is recommended for HDPE pipes based on the load response of the truck and repeated load surges. As part of the irrigation pipeline project.

Hiroyuki Tamura (2006) conducted an experiment using a steel pipe with a diameter of 3500 mm and a thickness of 26 mm. Two different search strategies were used in the field trials. For Case 1, the filler is soil cement and its height is half the pipe diameter from the soil. For Case 2, the soil cement backfill is a quarter of the diameter measured from the tube sheet. A mixture of recycled crushed concrete and crushed gravel was filled on top of the tube with soil cement. In both cases, the line is laid to a depth of approximately 3.0m. A displacement sensor is placed on the tube and a strain gauge is mounted inside the tube. Earth pressure sensors and pore water pressure transducers were installed in the backfill material around the pipeline. Growth is measured at every stage of the return process. It was found that the backfill method and external force have a great influence on the operation of the underground pipeline.

Yoshiyuki Mohri (2001) investigated the usefulness of geogrids to improve the buoyancy of underground pipelines due to buoyancy in a series of experiments with buried pipelines. The studies were carried out on a small sandy bed using tubes of 1100 mm diameter. Four different piping containment systems were placed around a buried pipe with a shallow depth of coating during the test. To improve the buoyancy of underground pipelines, gravel fill materials and geogrids are used as a preventive strategy. The addition of geogrid reinforcement for shallow ground cover depths results in reduced coverage at extremely shallow depths. Geogrid reinforcement experiments show that the dead weight of the underlying soil, as well as the flexural deformation of the reinforcement layers around the tube, contribute to the restraining forces of the tube buoyancy.

Toshinori Kawabata (2006) focused on pipes in a residential area of Yamanashi prefecture while constructing an embankment with a height of 47.1 meters. He used FKV pipe (glass fiber reinforced plastic mortar). He measured the pressure, deflection and stress in the pipe over a year. A comparison of the two current design methods was also performed based on the field data. A closed solution was constructed to

calculate the deflection and stress of the pipe according to the observed behavior. The study led to a new earth pressure map for the design of the embankment. The vertical earth pressure distribution was concave, with earth pressures 0.9 times and 1.1 times the average vertical earth pressure at the centre and end of the pipe, respectively. The average vertical earth pressure of the pipe head was 1.4 times the lateral earth pressure of the source line. This data was then used to develop a design scheme for flexible pipes laid under heavy embankments to calculate pipe deflection, stress, and bending moments. The calculation of pipe deflection and stress using the current design ground pressures of Spangler 1941 and JSWA 1999 does not match the observed data well, but the proposed pressure chart and analysis do. The results of the study helped to analyse the behaviour of pipes in large-scale fillings and to validate numerical and physical models in the future. B. Centrifugal model.

Madaswamy Arokiasamy (2006) conducted field tests on large calibre HDPE, PVC, and metal pipes that load road vehicles. Numerical simulations were performed using a finite element approach to estimate the reaction of the pipe soil system under traffic loads. Field test data were compared with the ground pressure around and above the pipe, the cross-sectional profile of the deformed pipe, and the predicted response of the pipe deflection. Field test results have shown that embedded flexible pipes embedded in highly compressed sloping sand containing silt work well without obvious joint openings or structural loads. The 5% deflection limit defined by AASHTO has been determined to be reasonable for installing flexible pipes during construction in shallow burial conditions. A 2% vertical deflection limit is recommended for HDPE pipes based on the load response of the truck and repeated load surges. As part of the irrigation pipeline project.

Hiroyuki Tamura (2006) conducted experiments using steel pipes with a diameter of 3500 mm and a thickness of 26 mm. Two different backfill strategies were used in the field trials. In Case 1, the backfill material was soil cement, half the height of the pipe diameter measured from the bottom. In Case 2, soil cement backfill was used to a depth of one quarter of the diameter measured from the tube sheet. A mixture of recycled crushed concrete and crushed gravel was backfilled onto the top of the pipe on earth line cement. In both cases, the pipeline is laid to a depth of about 3.0 m. A displacement sensor is placed on the pipe and a strain gauge is fixed inside the pipe. Soil pressure sensors and pore water pressure transducers have been installed in the fill material around the pipeline. The strain is measured at each stage

of the return process. It is found that backfill method and external force have a great influence on the operation of buried pipeline.

Galli and Prisco (2006) studied the mechanical interaction of a buried pipe with the surrounding soil. The aim of this study is to determine the stresses caused by slope instability, fault displacement and settlement caused by liquefaction of sand layers along the pipeline. Uncoated elastomeric rings are often used to represent interactions. Multiple inclined load directions were considered in this study, and remarkable coupling effects were found between different load components in experimental and computational studies. A test campaign using a small-scale model of a stressful aircraft situation has been detailed. Two distinct densities, as well as several diametrical depths, were examined to explain the influence of key geotechnical and geometrical features.

The connection between the vertical and horizontal directions was reconstructed using 2D FEM numerical analysis to model this splicing effect quantitatively. To simulate the vertical orientation, another membership model was used. Studies show that there is no appreciable coupling between the load components in the axial direction, as the system is mainly governed by the contact behaviour of the earth pipe. Finally, several periodic number experiments were performed to demonstrate the mechanical response of the system to seismic forces. Explaining the mechanical system is more difficult in this case because different and alternative failure modes can occur.

Gallage et al. (2008) investigated the behaviour of a 2 m long polyethylene pipe that was buried and tested in a reactive clay box. The pipe was 85 mm in diameter on the inside and 110 mm on the outside. The pipe was accessible from both ends of the box, which was 1015 mm long, 720 mm wide, and 1900 mm long. Using the wet condition technique, the clay had an initial water content of 13% and a dry density of 1.15 g/cm³. Moisture content, suction, and pipe and soil displacement were all observed over the course of 136 days of precipitation. The deflection was measured using a surveying level and a specially developed gadget inserted into the pipe. The pipe embedded in the soil box was then subjected to a simple numerical analysis using PROKON (Structural Analysis programme), which resulted in a comparison of computed and measured values, leading to the following findings.

Masada (2000) adapted Spangler's (1941) classic work to obtain a new formula for predicting the vertical deflection of flexible pipe. Spangler's technique was

rigorously followed throughout the derivation procedure. No additional assumptions or empirical aspects were incorporated beyond those originated by Spangler. The vertical deflection formula was created, and its accuracy was confirmed using Spangler's field deflection measurement data. The pipe-soil interaction problem, as highlighted by Spangler's work, was used in a few parametric experiments. It was finished by highlighting a few crucial considerations to keep in mind when using Spangler's classical method.

Carrier (2005) Deflection, rather than buckling, dictates the design of underground flexible tubing, according to research. Buckling, on the other hand, may be used to guide design in two scenarios: (1) shallow cover with internal vacuum pressure, and (2) shallow cover immersed in deep water with atmospheric internal pressure. The normal short-term deflection requirement of 3% should be altered in these cases to ensure that the deflection does not dictate the design.

Mohammad Gabar and Ömer Bilgin (2016) the mechanical behaviour of buried PVC pipe beneath the ground surface was explored. PVC pipes, load kinds, and soil layers The loads and soil layer behaviours were examined using finite element techniques and ABAQUS software to assess their impacts on buried PVC pipe. On any structural subsurface surface, from soil and live load. The use of varied soil layers resulted in increased vertical deformation when the loads were increased. This distortion may cause the pipe to buckle.

Fayez et al. (2012) investigated the influence of various factors on the behaviour of underground High Density Polyethylene (HDPE) pipes subjected to strike-slip faulting using large-scale and centrifuge tests, as well as finite element techniques.

Joshaghani and Alavi (2017) investigated potential slides in Tehran and selected them based on geometrical, geotechnical, and structural criteria. The performance of buried steel gas pipes with a diameter of 24 inches is numerically analysed using the ABAQUS programme against a local slope.

Nirmala et al. (2006) used experimental study and theoretical studies to evaluate the deformations of flexible UPVC pipes in loose soil conditions, and they recommend efficient techniques to lessen buried UPVC pipe deflections utilising geo reinforcing materials.

Fatih et al. (2013) investigated the effectiveness of WIB using various depths beneath the pipeline. The suggested model is investigated using 2D finite element analysis as a numerical simulation.

Spyros et al. (2011) investigated the design of underground welded steel pipes for water transmission and distribution using current literature as well as irrelevant regulations, standards, and design guides. techniques for analysing deformations Models of permanent ground deformation based on finite element analysis.

Tishkina et al. (2009) devised a pipeline fault crossing design that was based on the fault category. To improve pipeline safety during fault crossings, multiple safety classes of pipes are used, as well as a unique trench design based on soil permeability characteristics.

CHAPTER-3

AIM AND OBJECTIVE

3.1 AIM

- The main scope of this project is to maintain a proper transportation of the materials from one place to the other place without any kind of loss of the materials which are carried on these pipelines and also to provide a good quality of pipeline connection with the low cost.
- To attain these properties, we selected the UPVC pipes since it attains the characteristics which are needed and the main reason to be selected is due to its flexibility and long-life span compared to other sort of the pipeline materials which are being used.

3.2 OBJECTIVE

- To determine if factors, such as soil type, depth of burial, pipe diameter, pipe thickness and number of soil layers, are causing the pipeline to be diverted.
- Learn more about the interaction between pipes and soil under static loads. The height of the soil above the pipe varies in proportion to the diameter of the pipe.
- To offer efficient geo reinforcing materials for reducing buried UPVC pipe deflections.
- PLAXIS/ABAQUS, a finite element programme for evaluating the behavior of subterranean pipelines.

3.3 NEED FOR THE STUDY

- The study of underground pipe behaviour is important because it considers pipe safety.
- The primary phenomena are the study of the interplay between soil particle pressure and circumferential tension created around pipes.
- As the world becomes more urbanized, the use of subterranean pipes as a mode of fluid transportation is becoming increasingly important. This involves research into the design and performance analysis of landfill pipelines. The interaction between the surrounding soil and the pipeline determines the performance of the pipeline.

CHAPTER-4

METHODOLOGY

EXPERIMENTAL STUDY OF BURIED UPVC PIPES

4.1 GENERAL

This chapter describes the study on effects of static loading on UPVC pipe of 150mm (5 inches) internal diameter in terms of strain experienced by using LVDT, in the presence and absence of geo grids for various embedment depths along the soil box. The two-dimensional cross section of the tank is shown in *Fig: 4.1*

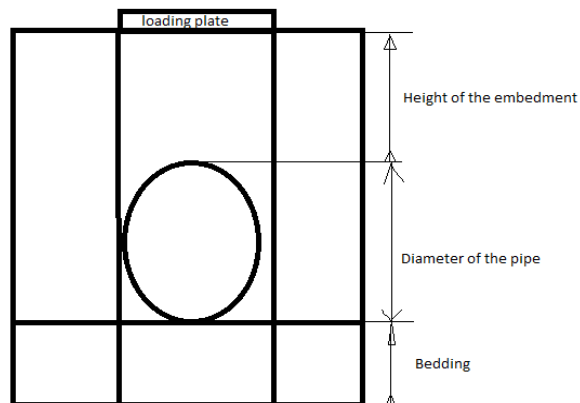


Fig: 4.1: Two-dimensional tank set up

To meet the objectives, the following methodology has been adopted as detailed in Fig 2.1.

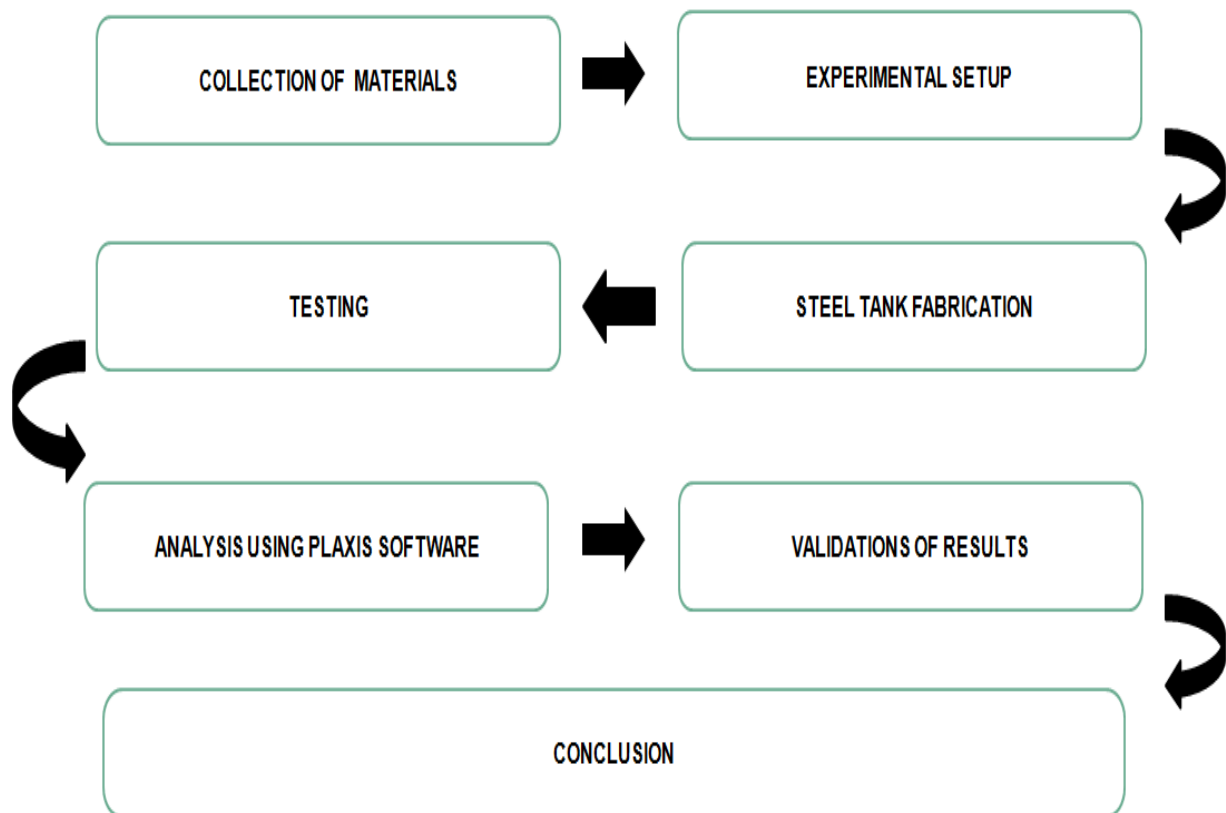


Fig: 4.2: Methodology

4.2 MATERIALS USED

4.2.1: Sand

1. Density of M sand = 15kN/m^3

4.2.2: Pipe

1. Type of pipe = UPVC
2. Diameter of the pipe = 150mm
3. Thickness of the pipe = 5mm
4. Density of the UPVC pipe = 0.15kN/m^3
5. Young's modulus of UPVC pipe (E) = $2.76 \times 10^6\text{kN/m}^2$
6. Poisson's ratio = 0.4

4.2.3 Loading Plate

1. Width of the loading plate =150mm
2. Thickness of the loading plate =20mm
3. Length of the loading plate =1m
4. Plate material =Mild steel
5. Density of mild steel =7850kg/m³
6. Nature of loading: STATIC loading

4.2.4 Geo grid

Geogrid is a composite material used to reinforce soil and other materials. Geogrids are commonly used to reinforce retaining walls as well as sub-basements or basements below.

Properties of geo grids

1. Aperture Shape -Diamond
2. Aperture Size -8 x 6 mm
3. Weight -730 + 73 gm /m²
4. Maximum Strength- 7.682 KN / m
5. Extension at maximum load -20.25 %

4.3 Experimental setup

The experimental set consists of a mild steel tank with the required dimensions and with that the tank is filled with sand in the mid of it pipe is used and loading plate is induced at the top of the tank with two dial gauges fixed at the both ends of the loading

plates



Fig:4.3: Experimental setup

4.3.1 Steel tank

Steel tank is fabricated using mild steel and is of dimensions of about 1 metre in length, 0.6 metre in breadth and 1.2 metre in height. The thickness of the MS plates is 10mm. The MS plates are welded using an arc weld with weld thickness around 6mm. Openings to insert pipe in the soil box are made on shorter side, an opening of diameter of around 180 mm is actually made to fit a pipe of external diameter of 165 mm. The shorter side of the box is fabricated in such a way so as to allow interchange of removable plates for various pipe embedment depths. The removable plates and the box are fitted together by means of using bolting system. Bolts of grade 10.8 and 10-mm diameter were used to hold the removable plates with the box. Openings were made in the removable plate at various heights ($h/d=1$, $h/d=2$, $h/d=3$, $h/d=4$) from the top of the tank corresponding to height of backfill to depth of embedment ratio.

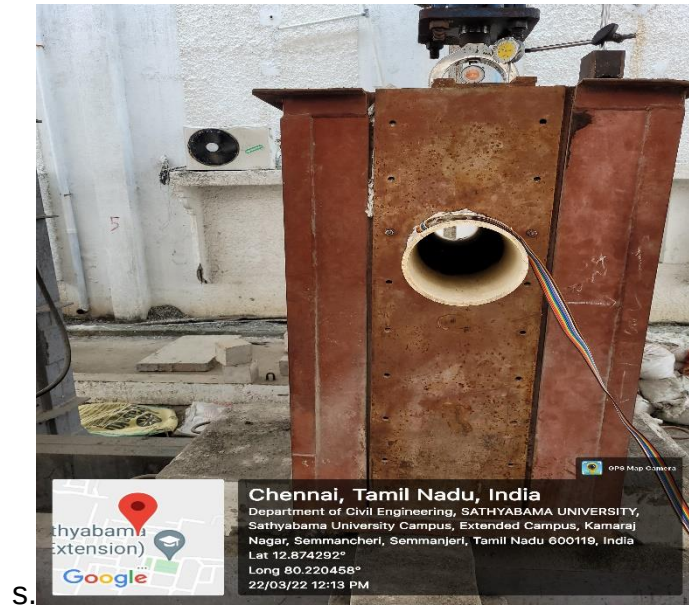


Fig:4.4: Fabricated steel tank

4.3.2 Strain Gauge

The experiment consisted of six strain gauges. Three strain gauges are attached perpendicular to the crown along the springing line, and the remaining three are fixed perpendicular to the crown in mutually perpendicular directions at the pipe's crown. These ties are demonstrated. 4.3 in Figure These strain gauges are attached to a normal LVDT and are used to measure the initial and changing stresses on the pipe as the load increases. Strain gauges have a 1.13-ohm resistance and a gauge factor of 2.13. To get strain measurements, a fake pipe is attached to the strain gauges.



Fig: 4.5: Strain gauge embedded in pipe

4.3.3 Loading Plate

A loading plate of different dimensions such as of (1000mmx150mmx20mm), (1000mmx200mmx20mm), (1000mmx250mmx20mm) are used to transfer the load from the loading frame onto the soil in the test box. The loading plate is additionally provided with bracings using steel flats of width 30mm and thickness 12mm. The bracings serve the purpose of transferring the point load from the frame onto the entire surface of the plate. The plate is also provided with a hemi spherical groove at the centre to accommodate a steel ball of diameter 12mm for transfer of load.



Fig: 4.6: Loading Plate

4.3.4 Dial Gauges

Two dial gauges were fitted over the loading plate from a stable base in order to measure the settlement of the plate during the loading process. The dial gauges chosen have a least count of 0.01 mm and maximum measurable deflection as 25mm. The dial gauges were fixed on diametrically opposite sides of the plate and the readings were noted down.



Fig: 4.7: Dial Gauge

4.3.5 Proving Ring

The proving ring is of 50kN capacities and the least count is of .02kN. The proving ring was attached to the loading frame and tied firmly and the other end was placed over the loading plate. Proper care was taken to ensure verticality and central alignment of the proving ring in order to avoid eccentric loading These are shown in *Fig: 3.4*



Fig: 4.8: Proving Ring

4.3.6 Loading Frame

A loading frame of capacity of around 50 tons is used to transmit the loads to the soil box. The soil box is loaded to around two tons by means of gradual increase in loading. The loading frame is of hydraulic in nature.

4.4 EXPERIMENTAL PROCESS

The experimental setup involves steel tank with the pipe inserted in the tank and filled with the soil.

- The tank is placed in the loading frame in the correct order and in the correct place
- The tank is then filled with the soil to the bedding with the pipe placed in the bedding level and the soil is filled to the tank level
- The loading plate is placed at the centre of the box and the steel ball and associated proving ring and its components are fixed. The fixing of the proving ring requires immense carefulness to avoid transfer of eccentric loads which may ultimately damage the proving ring. Simultaneously the dial gauges from a fixed base are rested over the loading plate around the central area from diametrically opposite sides. The proving ring and the dial gauges are set initially to zero.
- • The LVDT connected to the strain gauges in the pipes is then turned on, and the gauge factor is accurately adjusted. The first measurements for the strain over the six strain gauges are recorded by turning the nobs on the strain gauge from channel 1 to channel 6. Repeating the method to achieve average values and eliminate any instrument error, the LVDT is further checked for any value undulations.
- Once the initial set up is complete, the load is gently added to the soil, with readings corresponding to the two dial gauges and the LVDT taken every 2kN until the applied load reaches 20kN. Once the 20kN load has been attained, no more force is added, and the load is gradually released by reducing the hydraulic pressure.
- The loading plate, proving ring, and dial gauges are all removed and carefully stored away from the setup once the readings have been taken. Remove the loose sand from the box once more until the top of the bedding is gone. This prevents the loose backfill sand from becoming too dense. After sand removal until litter is reached, the tube is filled to a height of 20 cm from the top. The deposition of sand is stopped and the netlon geogrid is distributed over the entire surface when a height of up to 20 cm above the top is reached. The sanding process is repeated until the top of the box is reached.

- Once the geogrid is in place and the associated measurements are recorded, the same technique as in stages 3, 4, and 5 is performed to determine the strain in the pipe.
- Once a set of readings with and without geogrids are completed for a particular embedment depth, the removable plates are changed to perform the same experiment for a different embedment depth and the same process is repeated.

4.5 Plaxis

Plaxis is two- and three-dimensional engineering software that uses finite element methods to design and analyze the deformation and stability of soils and rocks, soil structure interactions, groundwater, and heat flows. PLAXIS software is used in a variety of applications including excavation, foundation, embankment, tunneling, mining and dredging. Advanced structural models are needed for geotechnical applications to simulate the nonlinear and time-dependent soil behavior. In addition, because soil is a multiphase material, unique processes are needed to resolve hydrostatic and non-hydrostatic pore pressure in soil. While soil modeling is important in itself, many geoengineering projects also require modeling of structures and their interactions with the soil. PLAXIS software has unique capabilities to handle many aspects of complex geotechnical engineering. The user-friendly interface guides the user through a streamlined geotechnical process to build models efficiently. Users can define complex soil configurations or geological profiles using boreholes. Structural elements such as piles, anchors, geotextiles, specified loads and displacements can all be specified in Structure mode. CADD files can also be used to import geometry. The automatic meshing process quickly generates a finite element mesh. The user can accurately reproduce the construction process using phased construction by activating and deactivating soil groups and structural elements during each calculation phase. A wide range of geotechnical problems can be studied using various types of plasticity analysis, consolidation and safety computation.

A wide spectrum of soil and rock behaviour can be modelled using constitutive models, ranging from simple linear models to extremely advanced nonlinear models. Convergent calculations and accurate results are ensured by rigorous and proven computational techniques. PLAXIS can handle the largest and most complex models thanks to multi-core computing and 64-bit architecture. In contour, vector, and plane

graphs, Output software displays forces, displacements, stresses, and flux data in different ways. The data can be further explored using cross-sectional tools. Data can be transferred from tables or processed outside of PLAXIS using Python programming.

The Curve Manager permits you to create graphs through charting diverse styles of consequences the usage of to be had calculation data. It is essential to set up a geometrical version earlier than analysing any new project. A geometry version, that is made of points, lines, and clusters, is a two-dimensional illustration of a 3-dimensional issue. A geometry version ought to include a illustration of the subsoil's separation into separate soil layers, in addition to structural items, constructing phases, and loadings. The version have to be massive sufficient that the borders do now no longer have an effect on the consequences of the hassle being investigated. A designated description of the 3 styles of additives in a geometry version can be located below.

Point:

The beginning and end of a line are marked with a period. Points can be used to provide anchors, point forces, fixation points, and local enhancements to finite element meshes.

Lines:

Lines are used to define physical boundaries of geometries, model boundaries and discontinuities in geometry such as walls or shells, separations of separate soil layers, or construction phases. A stream can have several functions or properties.

Clusters:

A cluster is a place that is completely lined. PLAXIS automatically recognizes the cluster based on the input of the geometry line. The quality of the soil in the cluster is uniform. As a result, the cluster can be considered a component of the soil layer. Cluster-related actions apply to all elements in the cluster. After you create a geometry model, you can automatically build a finite element model based on the configuration of the geometry model's clusters and lines. Finite element meshes can recognize three types of components, as described below.

Elements:

The clusters are divided into triangular pieces during mesh manufacturing. There are

15 button elements and 6 button elements to choose from. The 15-node solid element allows for precise stress and failure load calculations. In addition, the 6-node triangle can be used to quickly compute service states. When considering the distribution of the same elements (e.g., default raw mesh generation), the user should be aware that meshes consisting of 15 node elements are significantly better and more flexible than the mesh is made up of 6 node elements, but the calculation takes more time. Compatible plate, geogrid and interface elements, In addition to triangular components commonly used to mimic soils, structural behavior and soil structure interactions can be modeled.

Node:

The displacements at the nodes are determined during the finite element computation. For the creation of load displacements, nodes may be pre-stressed.

The analytical output model of the experimental work are shown *fig3.5*

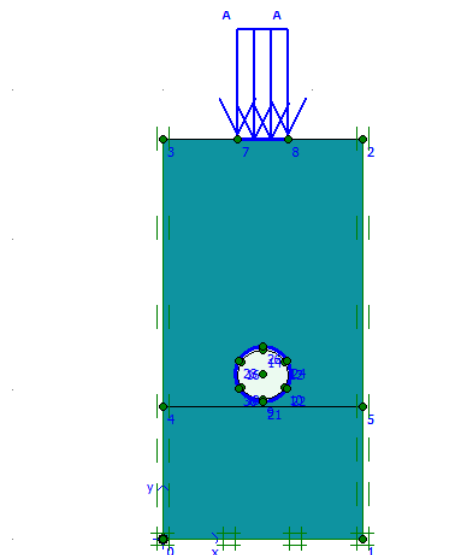


Fig: 4.8: Analytical set up of the tank

CHAPTER-5

RESULTS AND DISCUSSION

Table 5.1 Strain and deflection figures for a 150mm wide loading plate without a geogrid at h/d=1.

Load (KN)	Deflection	Deflection	Strain@ Location1	Strain@ Location2	Strain@ Location3	Strain@ Location4	Strain@ Location5	Strain@ Location6
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.50	1.60	-154	-46	-168	348	130	67
4	2.80	2.30	-445	-244	-430	521	452	133
6	4.30	3.50	-610	-810	-1031	702	484	298
8	6.80	5.70	-640	-1058	-1166	1109	571	533
10	12.60	11.30	-911	-1146	-1355	1219	621	844
12	18.80	17.50	-1043	-1188	-1769	1603	749	1042
14	22	21.20	-1221	-1250	-1678	1691	805	1153
16	24.20	23.55	-1251	-1468	-1798	1811	876	1370
18	29	27.6	-1267	-1608	-2178	1966	999	1709
20	31.4	30.2	-1278	-1658	-2366	2011	1105	1955

Table 5.2 Strain and deflection figures for a 150mm wide loading plate with a geogrid at h/d=1.

Load (KN)	Deflection	Deflection	Strain@ Location1	Strain@ Location2	Strain@ Location3	Strain@ Location4	Strain@ Location5	Strain@ Location6
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.20	1.30	-315	-157	-172	271	158	-53
4	1.50	1.60	-553	-366	-431	490	434	39
6	2.80	2.70	-726	-747	-1049	768	511	245
8	8.30	7.50	-792	-940	-1145	1132	583	318
10	10.80	9.70	-1037	-1160	-1337	1183	695	320
12	14.60	13.30	-999	-1248	-1632	1625	794	760
14	18.80	17.50	-1228	-1373	-1723	1714	807	996
16	20	19.20	-1333	-1328	-1754	1830	860	1257
18	25.20	24.98	-1353	-1594	-2144	1990	879	1606
20	28.75	29.5	-1482	-1690	-2231	2056	1096	1913

Table 5.3. Strain and deflection figures for a 150mm wide loading plate without a geogrid at $h/d=2$.

Load (KN)	Deflection	Deflection	Strain@ Location1	Strain@ Location2	Strain@ Location3	Strain@ Location4	Strain@ Location5	Strain@ Location6
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.50	1.60	-154	-146	-168	348	130	-757
4	2.80	2.70	-445	-344	-430	521	452	-823
6	4.30	4.50	-610	-910	-1031	702	484	-988
8	6.80	5.70	-640	-1158	-1166	1109	571	-1223
10	11.60	10.30	-911	-1246	-1355	1219	621	-1534
12	14.80	13.50	-1043	-1288	-1769	1603	749	-1732
14	18	17.20	-1221	-1350	-1678	1691	805	-1843
16	25.20	25	-1251	-1568	-1798	1811	876	-2060
18	27	26.3	-1267	-1708	-2178	1966	999	-2399
20	29.67	28.99	-1278	-1758	-2366	2011	1105	-2645

Table 5.4 Strain and deflection figures for a 150mm wide loading plate with a geogrid at $h/d=2$.

Load (KN)	Deflection	Deflection	Strain@ Location1	Strain@ Location2	Strain@ Location3	Strain@ Location4	Strain@ Location5	Strain@ Location6
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.20	1.30	-315	-157	-172	271	158	-562
4	3.50	2.60	-553	-366	-431	490	434	-654
6	5.80	4.70	-726	-747	-1049	768	511	-860
8	8.30	7.50	-792	-940	-1145	1132	583	-933
10	11.80	10.70	-1037	-1160	-1337	1183	695	-935
12	12.60	12.30	-999	-1248	-1632	1625	794	-1375
14	16.80	15.50	-1228	-1373	-1723	1714	807	-1611
16	22	21.20	-1333	-1328	-1754	1830	860	-1872
18	27.20	26.2	-1353	-1594	-2144	1990	879	-2221
20	28.76	29.95	-1482	-1690	-2231	2056	1096	-2528

5.2 VERTICAL AND HORIZONTAL DEFLECTIONS VALUES

Table 5.5 Strain and deflection figures for a 150mm wide loading plate at $h/d=1$ without a geogrid

Load	Dial gauges (mm)	Strain @A	Strain @B	Vertical deflections	Horizontal deflections
2	1.55	-93.6	602	-0.1405	0.903
4	2.55	-344	789	-0.516	1.1835
6	3.9	-788	915	-1.182	1.3725
8	10.15	-925.66	1158	-1.3885	1.737
10	14.88	-1108.3	1315	-1.6625	1.9725
12	18.15	-1304.3	1551.66	-1.9565	2.3275
14	21.6	-1354	1636.66	-2.031	2.455
16	23.875	-1476.7	1772.66	-2.215	2.659
18	28.3	-1655.3	1978.33	-2.483	2.9675
20	38	-1738.3	21167	-2.6075	3.166

Table 5.6 Strain and deflection figures for a 150mm wide loading plate at $h/d=1$ with a geogrid

Load	Dial gauges (mm)	Strain @A	Strain @B	Vertical deflections	Horizontal deflections
2	1.25	64.66	5467	-0.097	0.811
4	1.55	-1766	736.33	-0.256	1.1045
6	2.75	-561.33	923.33	-0.842	1.385
8	7.9	-679.66	1093	-1.0195	1.6395
10	12.5	-898.66	1148	-1.348	1.722
12	13.95	-1013.7	1475	-1.5205	2.2125
14	18.15	-1162	1587.66	-1.743	2.3815
16	19.6	-1192.3	1731	-1.7885	2.5965
18	25.09	-1417.7	1907	-2.1265	2.8605
20	29.125	-1521.7	2103.66	-2.2825	3.1555

Table 5.7 Strain and deflection figures for a 150mm wide loading plate at $h/d=2$ without a geogrid

Load	Dial gauges (mm)	Strain @A	Strain @B	Vertical deflections	Horizontal deflections
2	1.55	-46.66	649	-0.07	0.9735
4	2.75	-297	836	-0.4455	1.254
6	4.4	-741	962	-1.1115	1.443
8	8.25	-878.66	1205	-1.318	1.8075
10	13.95	-1061.3	1362	-1.592	2.043
12	14.15	-1257.3	1598.66	-1.886	2.398
14	17.6	-1307	1683.66	-1.9605	2.5255
16	25.1	-1429.7	1819.66	-2.1445	2.7295
18	26.65	-1608.3	2025.33	-2.4125	3.038
20	29.33	-1691.3	2157.66	-2.537	3.2365

Table 5.8 Strain and deflection figures for a 150mm wide loading plate at $h/d=2$ with a geogrid

Load	Dial gauges (mm)	Strain @A	Strain @B	Vertical deflections	Horizontal deflections
2	1.25	6.66	482.66	-0.01	0.724
4	2.05	-228.66	678.33	-0.343	1.0175
6	3.9	-619.33	865.33	-0.929	1.298
8	7.9	-737.66	1035	-1.1065	1.5525
10	12.3	-956.66	1090	-1.435	1.635
12	12.45	-1071.7	1417	-1.6075	2.1255
14	16.15	-1220	1529.66	-1.83	2.2945
16	21.6	-12533	1673	-1.8755	2.5095
18	25.67	-1475.7	1849	-2.2135	2.7735
20	28.3	-1579.7	2045.66	-2.3695	3.0685

5.3 GRAPHICAL REPRESENTATION OF THE TEST RESULT

The following graphs show the load vs deflection and load vs settlement

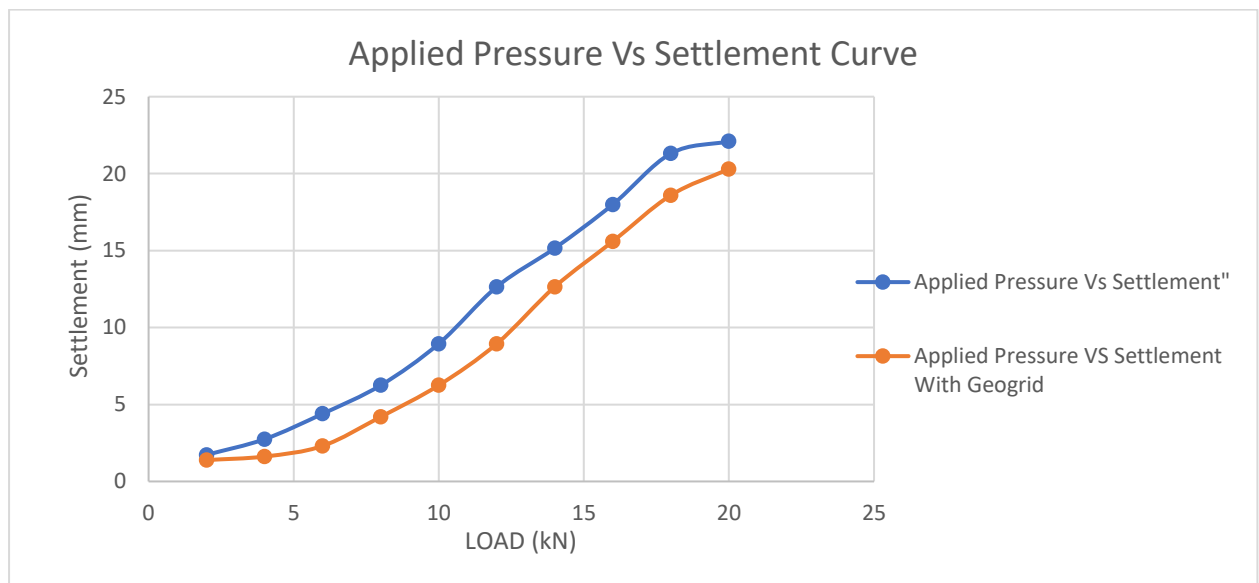


Fig: 5.1: Load vs settlement curve for $h/d=1$ (without and with geogrid) for 150mm width loading plate

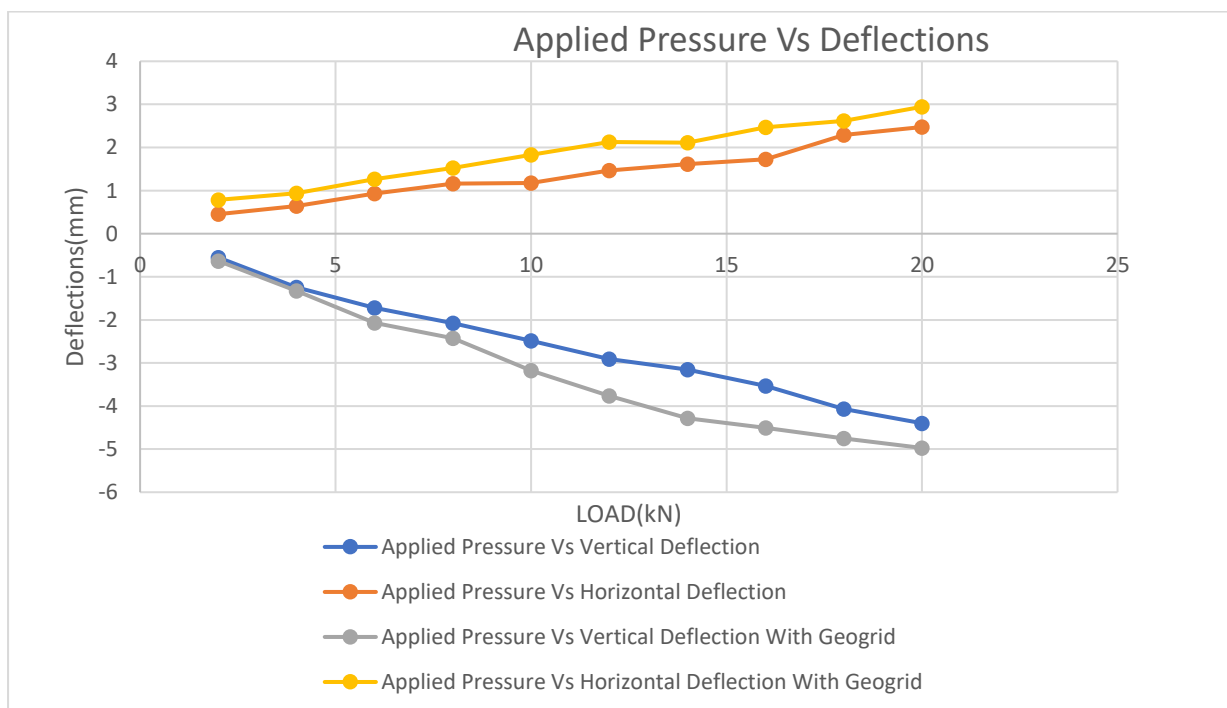


Fig: 5.2: Load vs deflection curve for $h/d=1$ (without and with geogrid) for 150mm width loading plate

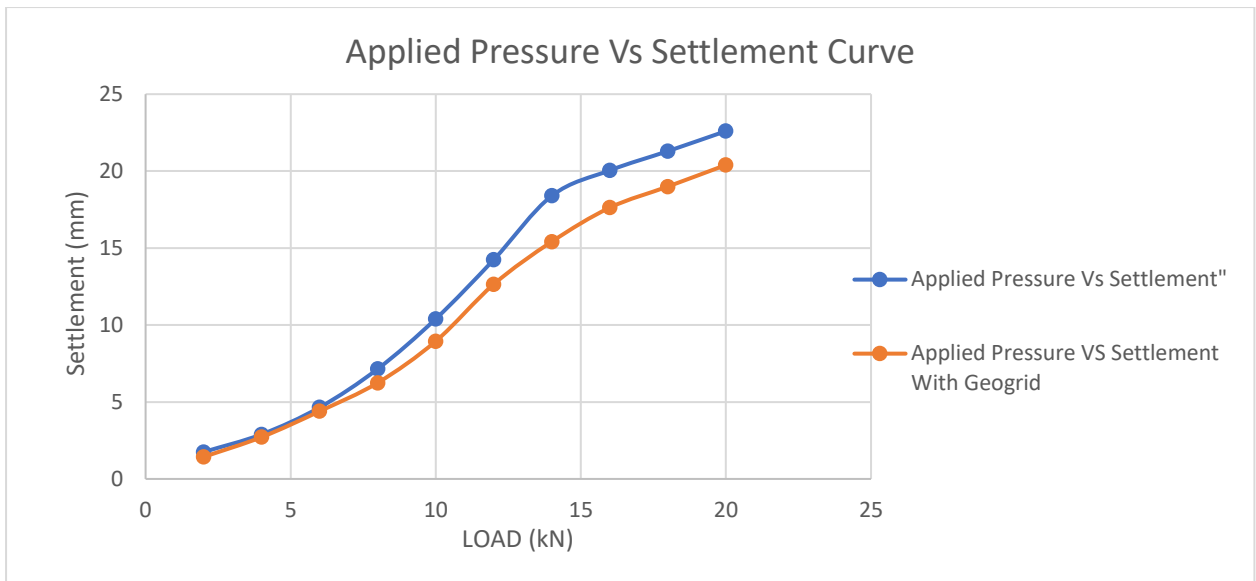


Fig: 5.3: Load vs settlement curve for $h/d=2$ (without and with geogrid) for 150mm width loading plate

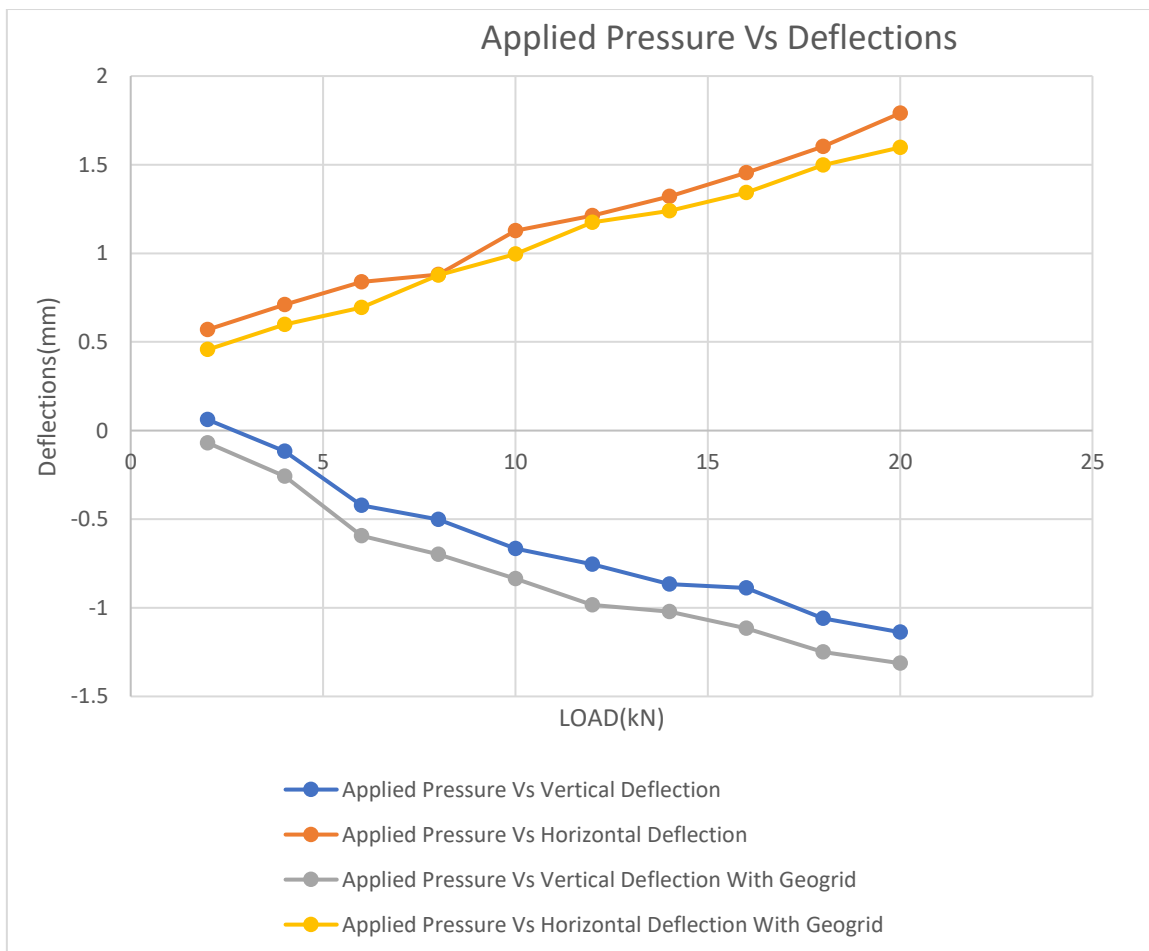


Fig: 5.4: Load vs deflection curve for $h/d=2$ (without and with geogrid) for 150mm width loading plate

5.4 COMPARISON OF EXPERIMENTAL AND PLAXIS RESULTS

The experimental and analytical values are compared and tabulated below the following tables

Table 5.9: Comparison of Experimental & Plaxis results of Strain and Deflection values at $h/d=1$ with geogrid with 150mm width loading plate

EXPERIMENTAL RESULTS		PLAXIS RESULTS	
Vertical deflections	Horizontal deflections	Vertical deflections (mm)	Horizontal deflections (mm)
-1.115	0.8795	-0.135	0
-2.485	1.2485	-1.505	0.5655
-3.436	1.8275	-2.456	1.1445
-4.1385	2.29	-3.1585	1.607
-4.944	2.319	-3.964	1.636
-5.7925	2.8875	-4.8125	2.2045
-6.28	3.18	-5.3	2.497
-7.0305	3.399	-6.0505	2.716
-8.548	4.529	-9.5675	3.846
-9.752	4.892	-9.772	4.209

Table 5.10: Comparison of Experimental & Plaxis results of Strain and Deflection values at $h/d=2$ with geogrid with 150mm width loading plate

EXPERIMENTAL RESULTS		PLAXIS RESULTS	
Vertical deflections	Horizontal deflections	Vertical deflections (mm)	Horizontal deflections (mm)
-1.1185	0.875	-0.1385	0.192
-2.4885	1.244	-1.5085	0.561
-3.4395	1.823	-2.4595	1.14
-4.142	2.2855	-3.162	1.6025
-4.9475	2.3145	-3.9675	1.6315
-5.796	2.883	-4.816	2.2
-6.2835	3.1755	-5.3035	2.4925
-7.034	3.3945	-6.054	2.7115
-10.551	4.5245	-7.571	3.8415
-10.756	4.8875	-8.7755	4.2045

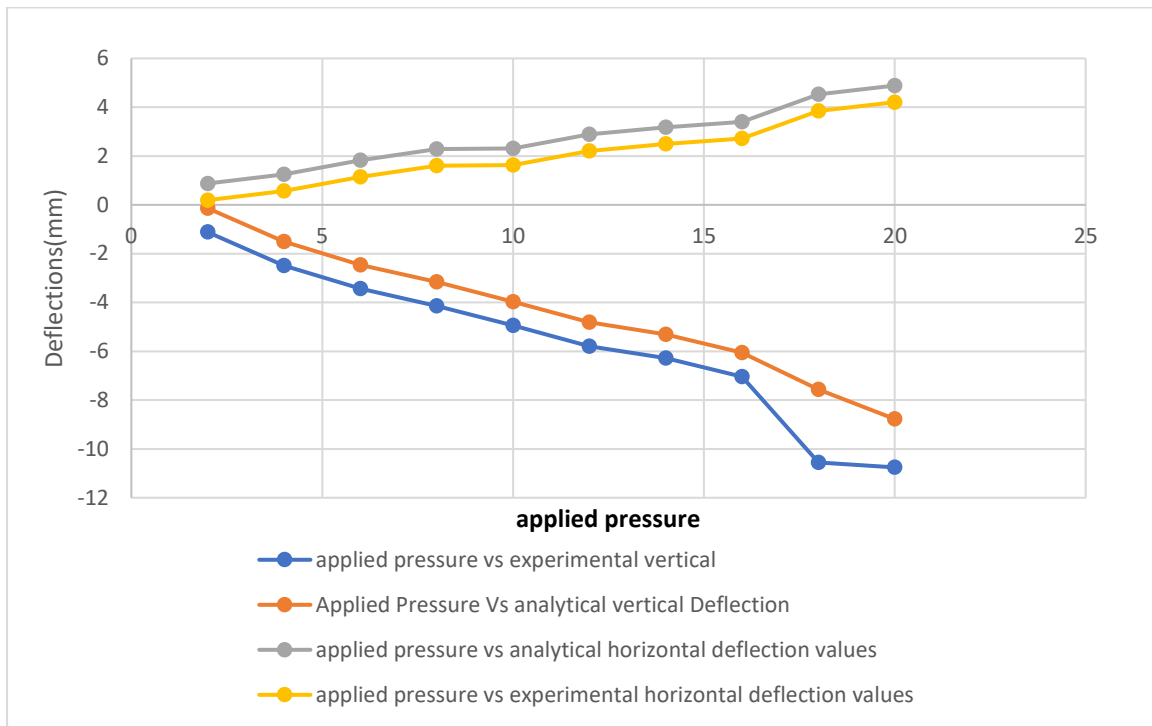


Fig: 5.5: comparison of experimental and analytical values at $h/d=1$

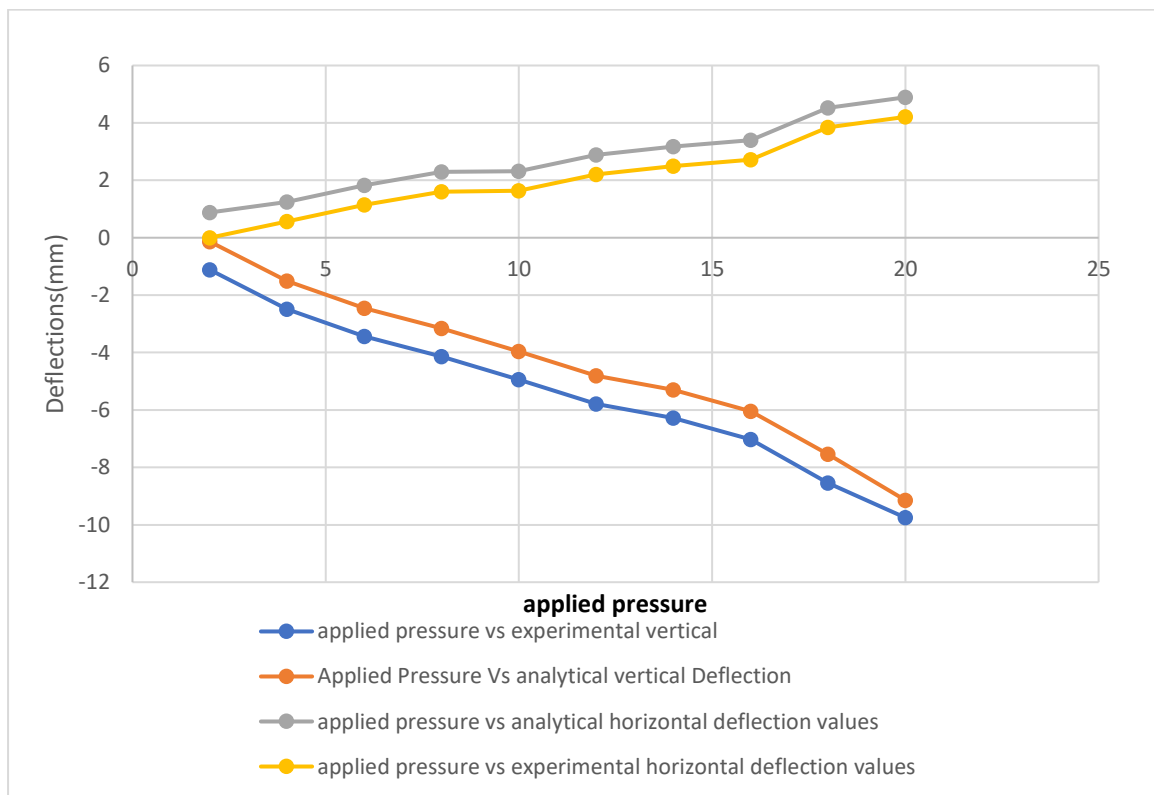


Fig: 5.6: comparison of experimental and analytical values at $h/d=2$

CHAPTER-6

CONCLUSION

6.1 SUMMARY

From the study of the various results obtained, the conclusions are presented below

- As the ground cover increases it reduces the stress in the pipe and if the ground cover increases the stress rate in the pipe decreases hence the pipe at the height velocity at $h/d = 2$ reaches the minimum limit.
- The presence of the geo grid also helps in the reduction of the strain in the pipe the geo grid which is placed at the height of above 2mm above the crown level helps in the reduction of the strain in the pipe to a certain extent of about 25 %.
- The deflection in the pipe at the height of $h/d=1$ is maximum and it has a limiting value which is depended by the thickness of the pipe.
- Experimental and the analytical values proves that the pipe with the high radius produces a maximum deformation compared to the pipe with lower radius

6.2 CONCLUSION

Thus the connectivity with pipe in this experiment proved that the connection of underground pipes with the process of transferring the materials can be achieved and could be done with the help of the UPVC pipes at a lesser cost and with a less maintenance compared to steel and concrete pipes and this method of pipe lines are easily accessible and can be maintained. In case of the pipe with the lower height may experience the stress due to the load imposed on it to avoid it the of the embedment height should be less with the increase in the pipe diameter placing a geo grid in the crown of they may help in the temporary prevention of the stress in the pipe and may also reduce to 25% of the strain in the pipe.

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This is to certify that **Binson C Johnson** of **Sathyabama Institute of Science and Technology** has presented the paper titled **EXPERIMENTAL AND NUMERICAL STUDIES ON UN-PLASTICIZED POLY VINYL CHLORIDE PIPE BURIED IN M-SAND** in the International Conference on *Science, Innovation, Sustainable, Technology - Safety, Health and Environment 2022 (SIST-SHE22)* conducted by the Department of Biomedical, Chemical and Civil Engineering, Sathyabama Institute of Science and Technology, Chennai, on 8th - 10th March, 2022.

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