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An experimental study of buried PVC pipes

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ABSTRACT: The behavior of PVC pipes has been studied in this paper with a view to exploring its use in a wide area of civil engineering constructions. The principal application of polyethylene pipes is in agriculture, construction industry, highways and roads. In the design of flexible pipes, the deflection plays an important role. So the relationship between crest deflection with load, type of soil, length to diameter ratio and depth of burial has become an important part in the buried pipe design. Due to the variability of soil type, bedding material, depth of burial, length to diameter ratio, material property, etc. analysis and design of pipe need proper consideration of all the above factors. The objective of this research is to investigate the load-deformation behavior of PVC pipes buried under Dhaka clay. The basic investigation has been carried out by laboratory experiments on PVC pipes under reconstructed Dhaka clay. The aims of the investigation are (a) to investigate the load-deflection curves of different diameter PVC pipes at various depths in Dhaka clay (b) to investigate the effect of soil density on deformation of buried PVC pipe and (c) to find out the effect of diameter and surface stiffness (flexibility) of buried PVC pipe on pipe deformation.

1 INTRODUCTION

The use of Polyvinyl chloride (PVC) pipes is increasing day by day around the world. The popularity of using PVC pipe for different purposes is increasing sharply in Bangladesh as well. The principal application of polyethylene pipes is in agriculture, construction industry, highways and roads. Its wide acceptance in this varied application is primarily due to (1) ease of installation, (2) lightweight, (3) resistance to corrosion, (4) unique structural properties, (5) resistance to abrasion and, above all, (7) low cost. Agricultural application is limited to farm drainage. In construction industry their application is mainly related to culvert pipe, storm sewer system, dam overflow, dredge spoil de-watering, toe drains for earth dams and levees etc. For highways and roads the application is related to airport runway drainage system, culverts, telephone line connections and electric line connections. In Bangladesh PVC pipes are being used in various ways. Most of them are used as buried culverts for the drainage of water across roads and embankments. Use of PVC pipes as sewer systems, underground telephone, electricity, gas and water distribution system is increasing.

1.1 *Objectives*

In order to design a flexible pipe, the deflection plays an important role. So the relation between crest deflection with load, type of soil, length to diameter ratio and depth of burial has become an important part in the buried pipe design. Due to the variability of soil type, bedding material, depth of burial, length to diameter ratio, material property etc. analysis and design of pipe needs proper consideration of all the above factors. In Bangladesh, PVC pipe is a relatively new construction material. It has to be properly tested and calibrated with respect to the soil of Bangladesh. In order to do that, a scheme has been taken to conduct several model tests on PVC pipes buried under Dhaka clay.

The objective of this research is to investigate the load-deformation behavior of PVC pipes buried under Dhaka clay. Accordingly, basic investigation is carried out by laboratory experiments on PVC pipes under Dhaka clay. The aims of the investigation are:

1. To draw load-deflection curves for different diameter PVC pipes at various depths in Dhaka clay.
2. To investigate the effect of soil density on buried PVC pipe deformation.
3. To find the effect of diameter and surface stiffness (flexibility) of buried PVC pipe on pipe deformation.

2 MODEL TESTS

2.1 *Method of Testing*

PVC pipe was placed in a large laboratory soil-box. The inside dimensions of the soil-box was 2.1m long, 2.1m wide and 2.2m high. A total of 10 PVC pipes of different diameters were buried at different depths to find out the deformation due to incremental loading until a visible failure on the ground took place. The pipes were buried at three different depths 0.61 m (2ft), 0.91 m (3ft) and 1.22m (4ft) from the top. The test was carried out in dry Dhaka clay. Dhaka clay is a highly plastic clay. Lumped clay was powdered first and a bed was prepared in five layers. In order to check the consistency of the density, several buckets were placed around the PVC pipes.

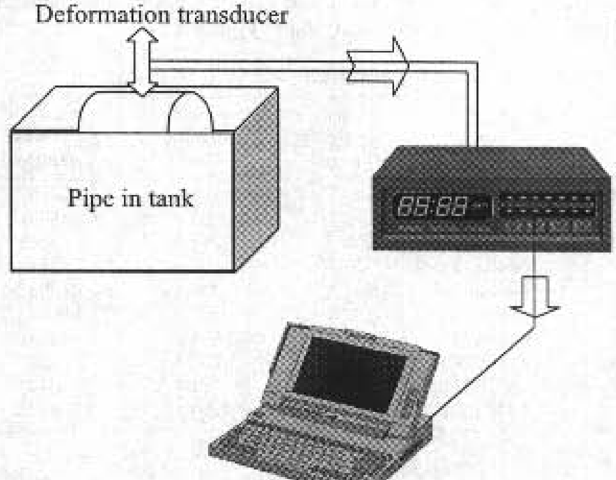

Figure 1 Schematic diagram of the model test showing pipe in the tank, data logger ADU 700 and the Laptop.

A special arrangement was made to hold the electronic deformation transducer on the surface of the pipe. Load was applied through a joist so that it was distributed over the length of the pipe simulating a plane strain condition. The rate of application of the load was rather fast. It was so done in order to simulate truck loading on the road. All the loading were carried out up to the standard truck loading. The pipes were corrugated on the surface. The surface roughness was of square wave shape. Although, surface roughness has a very important role in the load transfer mechanism of the pipe to the soil underneath, at this moment it was not varied. So the surface roughness was considered to be a fixed parameter. Direct shear tests were conducted to determine the angle of internal friction between the surface of the pipe and the soil. The property of Dhaka clay was thoroughly investigated by conducting laboratory tests.

All the load-deformation data were collected directly from the deformation transducer and stored in a lap-top computer through ADU-700 data logger (Figure 1). The data logger sampled 100 data points over 10 sec time and averaged it to produce the result.

2.2 *Material Properties*

The Dhaka clay bed was prepared inside the tank in five layers. Each layer was prepared with a fixed number of blows to attain a certain level of density. The density was measured by placing four buckets at the level of the lowest point of the pipe and then filling them with Dhaka clay. The soil was further tested in triaxial test to measure its strength and deformation property. The density and strength-deformation properties did not vary too much among different tests. The material property of the pipe has been assumed to be standard PVC property.

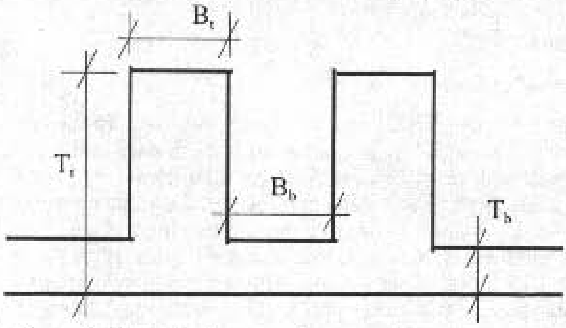

Figure 2 Typical diagram of corrugation on the surface of pipes.

The geometric property and dimension of the pipes are shown in the following tables (Table 1 and 2). The corrugation (surface roughness) is described according to Figure 2.

Table 1. Types of PVC pipes tested under static truck loading

Serial No.	Nominal Diameter mm(inch)	Outer Diameter (mm)	Inner Diameter (mm)	Length Tested (mm)
1	101.6(04)	120.7	101.6	1016.0
2	203.2(08)	120.7	101.6	889.0
3	254.0(10)	266.7	242.9	876.3
4	304.8(12)	320.7	298.5	1244.6
5	406.4(16)	431.8	400.1	1003.3
6	508.0(20)	539.8	501.7	1016.0
7	609.6(24)	638.2	584.2	990.6
8	711.2(28)	857.3	787.4	1028.7
9	787.4(31)	863.6	787.4	1047.8
10	1016 (40)	1073.2	990.6	1092.2

Table 2. Types of corrugation in PVC pipes tested under static truck loading (Fig. 2)

Serial No.	Corrugation per ft (0.3048m)	Dimension of corrugation T_t (mm)	B_t (mm)	B_b (mm)	T_b (mm)
1	17	9.5	7.9	7.9	2.38
2	11	11.1	9.5	9.5	2.38
3	11	12.7	11.1	15.9	2.38
4	11	15.9	12.7	15.9	2.38
5	8	15.9	17.5	20.6	2.38
6	7	19.1	22.2	28.6	3.17
7	6	25.4	28.6	31.8	3.97
8	5	34.9	31.8	38.1	4.76
9	5	34.9	31.8	38.1	4.76
10	4	41.3	44.5	44.5	6.35

3 RESULT AND DISCUSSION

Figures 3 through 9 show the load-deflection behavior of pipes. Pipe diameters are increasing in increasing sequence of the figure numbers. Each figure depicts the effect of the depth of embedment of the pipes inside the soil as well. Load carrying capacity of the pipes increase with the increase in pipe embedment depth. It is clear from the figures that all the pipes at a depth of embedment of 2 ft. showed low load carrying capacity (or larger deformation) than those of the pipes at a depth of 3 ft or 4 ft. Pipes at a depth of embedment of 3 ft. or 4 ft. showed puzzling results. The low diameter pipes (8in, 16 in) showed higher carrying capacity at greater depth (4 ft.) but higher diameter pipes showed lower carrying capacity at greater depth (4 ft.).

This can be explained as the effect of limiting clearance below the pipe base. As the pipe diameter increases and since the depth of the placement tank is fixed, the clearance below the base of the pipe decreases. Due to this limitation of the physical facility some of the tests with larger diameter pipes (31 in, 40 in) could not be performed with adequate accuracy and was discarded. The test of the pipe of diameter 4 in could not be done due to the lack of availability of space inside for the installation of electronic deformation transducer. Although tests were carried out up to a displacement of maximum 10% of pipe diameter, it can be observed from Figures 3 through 9 that stiffness of the pipes decreased drastically after a deformation range of 0.5% to 1.0% for most of the pipes.

Figures 10 through 12 show the load-defection plots of all pipes of various diameters for a particular depth. Figure 10 showed the load-defection (Loading only) curves of all the pipes of different diameters for a depth of 2 ft. Similarly, Figures 11 and 12 show the load-defection (Loading-Unloading) curves of all the pipes of different diameters for a depth of 3 ft and 4 ft, respectively. It is interesting to note that the last two cases showed loading and unloading behavior of the pipes. It showed initially linear elastic and finally nonlinear elastic (plastic) unloading for almost all the cases of pipe diameters.

The deformation of pipe was reduced with the increase of soil height over the pipe. The deformation depended on the density of the backfill. As it was expected, deformation decreased with the increase in density. In other words, the higher is the density the smaller is the deformation. The deformation also depended on the diameter of the pipe with a proportional relationship. The larger the diameter of the pipe, the higher was the deformation. For very large diameter pipes, there was an effect of confinement of the base of the soil-box. All the above graphical relationships provide a design guide for the practicing engineers of Bangladesh. Further tests are, however, deemed essential to consolidate the findings of the present study.

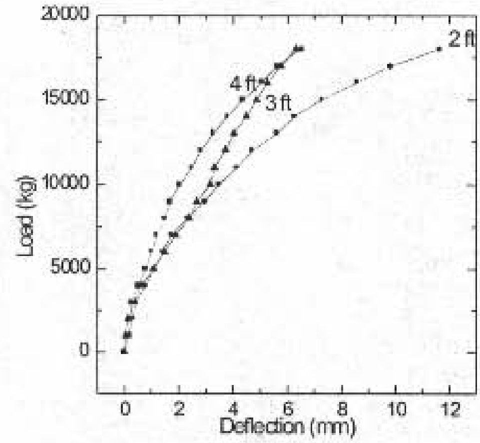

Figure 3 Load vs. deflection curves for 8-inch pipe at different depths (1 ft=30.48 cm, 1 in=2.54 cm).

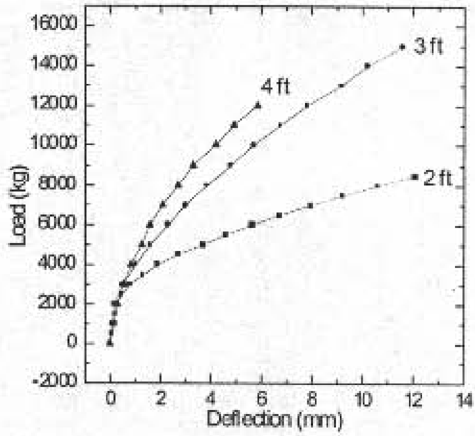

Figure 6 Load vs. deflection curves for 16 inch pipe at different depths.

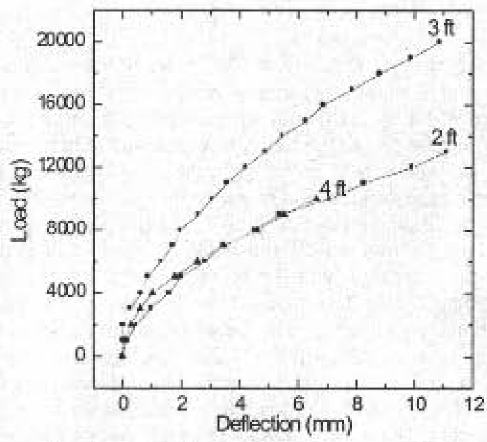

Figure 4 Load vs. deflection curves for 10 inch pipe at different depths.

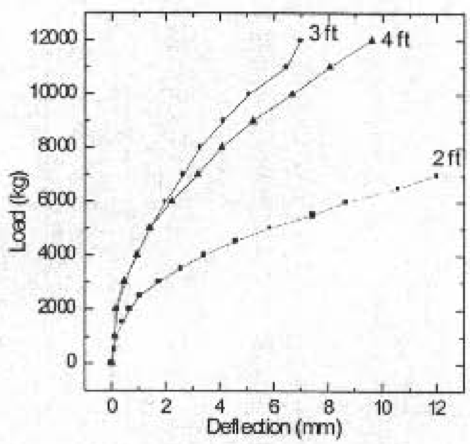

Figure 7 Load vs. deflection curves for 20 inch pipe at different depths.

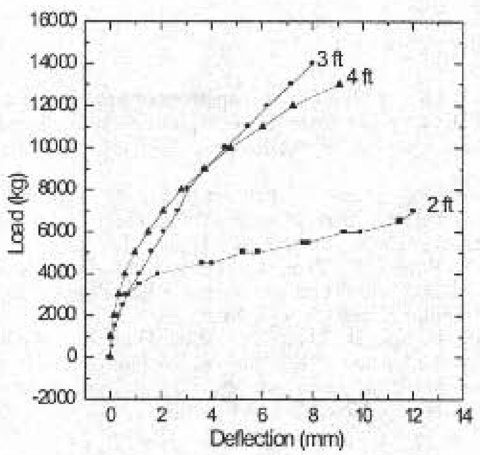

Figure 5 Load vs. deflection curves for 12 inch pipe at different depths.

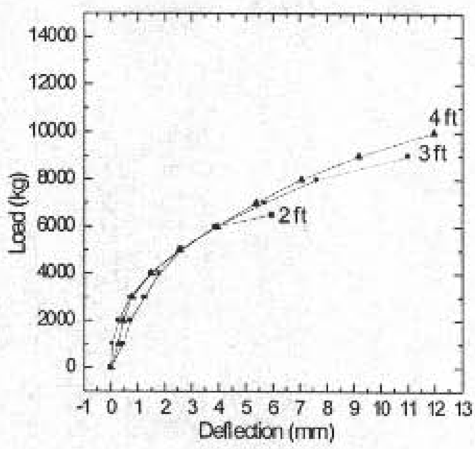

Figure 8 Load vs. deflection curves for 24 inch pipe at different depths.

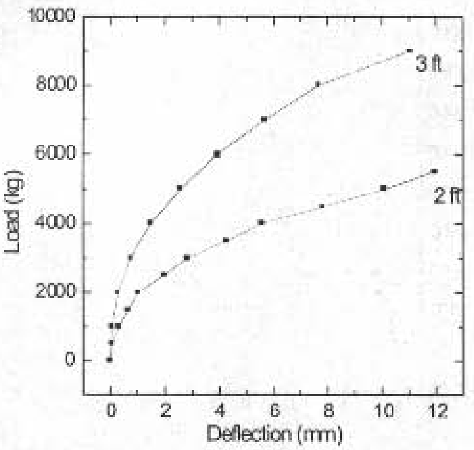

Figure 9 Load vs. deflection plot for 28 inch pipe at different depths.

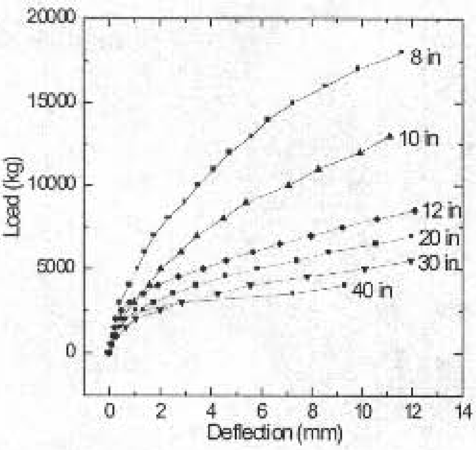

Figure 10 Load vs. deflection curves for all pipes at 2 ft. depth.

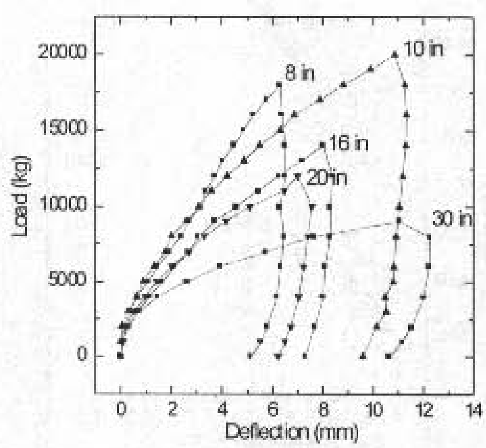

Figure 11 Load vs. deflection curves for all pipes at 3 ft. depth.

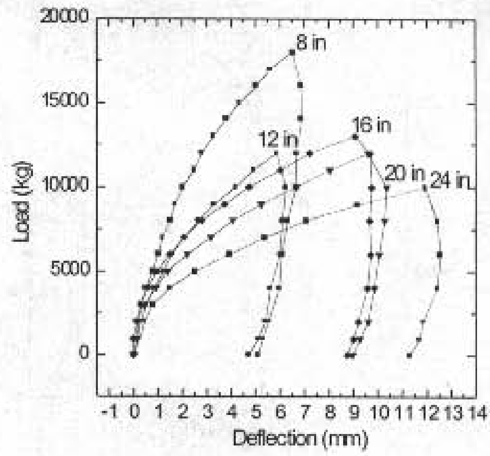

Figure 12 Load vs. deflection curves for all pipes at 4 ft. depth.

4 CONCLUSIONS

The load carrying capacity of PVC pipes of various diameters have been studied by performing model tests with automated data acquisition system and by placing the pipes at three different depths. The deformation of pipes was reduced with the increase of soil height over the pipe. The main reason of reduction in pipe deformation is due to the reduction in intensity of stress on pipe surface at greater depth. The deformation depended on the density of the backfill. As it was expected, deformation decreased with the increase in the density of soil. The deformation also depended on the diameter of the pipe with a proportional relationship. The larger the diameter of the pipe, the higher was the deformation. The loading and unloading behavior of the pipes showed initially linear elastic and finally nonlinear elastic (plastic) unloading for almost all the cases of pipe diameters. The plastic unloading part is probably due to the permanent deformation in the PVC pipe, which is reflected in the total deformation of the unloading curve.

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