IOSR Journal of Mathematics (IOSR-JM)
e-ISSN: 2278-5728, p-ISSN: 2319-765X. Volume 15, Issue 2 Ser. II (Mar – Apr 2019), PP 56-61
www.iosrjournals.org

Identifying the Optimum Path and the Positions of the Bends in PVC and DI Pipes in Underground Water Lines.

Dayan K.P.T.[1], Lanel G.H.J.[1], Lakmal U.S.V. [2]
[1]*Department of Mathematics, Faculty of Applied Sciences, Universityof Sri Jayewardenepura, Sri Lanka.*
[2]*National Water Supply & Drainage board, Sri Lanka.*
Corresponding Author: Dayan K.P.T.

***Abstract*:** *Consumable water distribution is a key service which is provided by any country. There are master plans working on this and from that proper piping systems are required for long term town and city projects to reduce maintenance, repairs and to continue the constructions cost effectively. Whole piping network consists of transmission region and distribution region to carry sufficient quantity of water from pumping station to the tower and from tower to the service areas. There is a special procedure to lay pipes called as concept of underground pipelines installation that is applied to keep the standardization of pipes by avoiding damages. In piping networks, bend is the most important part which helps to change the direction of the pipelines. (90, 45, 22½, and 11¼) degrees of angles are frequently implemented in bends. Compaction test, slump test, cube test, pressure test are done to maximize the quality and stability of bends indirectly. The aim of this research is to minimize the estimated total cost and project time, the amount of total bends of piping system, the head loss, internal pressure and friction of the pipes and bends and water leakages of pipelines in distribution region. As per these conditions, appropriate bending applications in pipelines must be created.*

The size of the population of the selected area is required to identify the pipe diameter and coordinates of bending path are required to identify the bend angle. Trench parameters (bedding, covering, surrounding) are measured to identify the horizontal and vertical placement of the bend according to the pipe diameter. Compaction test determines the quality of compacted soil that directly affects the load capacity of soil on bend. Slump test and cube test determine the workability and strength of concrete respectively, which can be directly used to identify the load capacity of thrust block on bend. The leakages on pipes and bends are determined by pressure test to identify the head loss of bends and thrust force in water. By analyzing developed mathematical algorithms for constructed constraints of each test and step, optimum solution is determined and total safety factor value for bends is also computed via bending application. The lower bound of the mathematical model of safety factor is 6.68.

Keywords: *bends, distribution region, head loss, safety factor, thrust blocks*

Date of Submission: 29-03-2019 Date of acceptance: 13-04-2019

I. Introduction

Water is one of the basic and essential needs for human life. Any one cannot spend day to day life without drinking water. Water is not only for purpose of drinking but also for purposes of bathing, cleaning, cooking, etc. People engage in many activities using water resources like oceans, rivers, lakes. Most of the activities are industrial based water projects. Briefly, we are unable to imagine a life without water. Conservation of water is very important for the survival in future.Water demand can be balanced when people are conserving water properly. But water demand increases as the rate of increasing population is increasing throughout the world. The per capita water demand (water consumption rate) mainly depends on climatic factors, presence of industries, quality and cost of water, etc. Actually, term of water demand comes from the agricultural, industrial and domestic sector. The time variations change the peaks of water demand like daily and hourly. On Saturdays and Sundays, water demand has a maximum rate of daily variation as well as at 7.00 p.m. to 8.00 p.m. water demand has a maximum rate of hourly variation in Sri Lanka.

National Water Supply & Drainage board launches many of water projects to reduce water demand in rural areas. Distributing water is the key responsibility of the board. Water distribution networks act as water distribution system to supply water. Transmission lines are used to carry sufficient quantity of water from source to storage and distribution lines are used to carry water from storage to sink through pipes [1]. These networks consist of pipes, pumps, valves (AOV, WV), bends, fittings, etc. Piping system is a rapid network in underground structures. There are different types of pipes mainly considering some parameters such as material type, diameter, brand, flexibility, etc. Some of them are PVC (Polyvinyl chloride), PE (Polyethylene), DI (Ductile Iron), GI (Galvanized Iron), etc. If we consider about the differences between PE and PVC, PE pipe is more flexible and it can deflect up to their allowable deflection limit without being damaged than PVC pipe. PVC pipe is unable to deflect as it has a rigid body. DI pipes are specially used as transmission water lines for flowing water from water pumping station to the tower. And also PVC pipes are used as distribution water lines for flowing water from tower to the service areas [1].

There is a special procedure to lay pipes in trenches and fill the trenches. This procedure is called as the concept of underground pipelines installation. Trench excavation, de watering, bedding, placing pipe in trench, pipe embedment, trench back fill, compaction are the main steps of that procedure [2]. Before trench excavation, TBM value should be found reference to the reduce level. Then coordinates of the area are taken using TS machine how to dig the trench. The concept of underground pipelines installation is basically used for constructing stable pipeline network. If laborers lay the pipes in trenches without any standard method then the pipes may be damaged. Therefore laborers have to dig trenches again and replace those damaged pipes. So, the total cost of the overall project is also increased. The engineers use three backfill layers to cover the pipes. Top layer consists of ABC (mixture of less than 32.5 mm sized stones) and other two layers consist of quarry dust (mixture of less than 1 mm soil particles) or selected soil or imported soil or sand [3].Bend is the most basic part in piping networks. It is very important to change the direction of water flow in piping system. The angle of a bend is considered as an anti-clockwise external angle. Some angles (90^0, 45^0, 22.5^0, 11.25^0) of bends are only used to construct the underground piping system in katana water project.

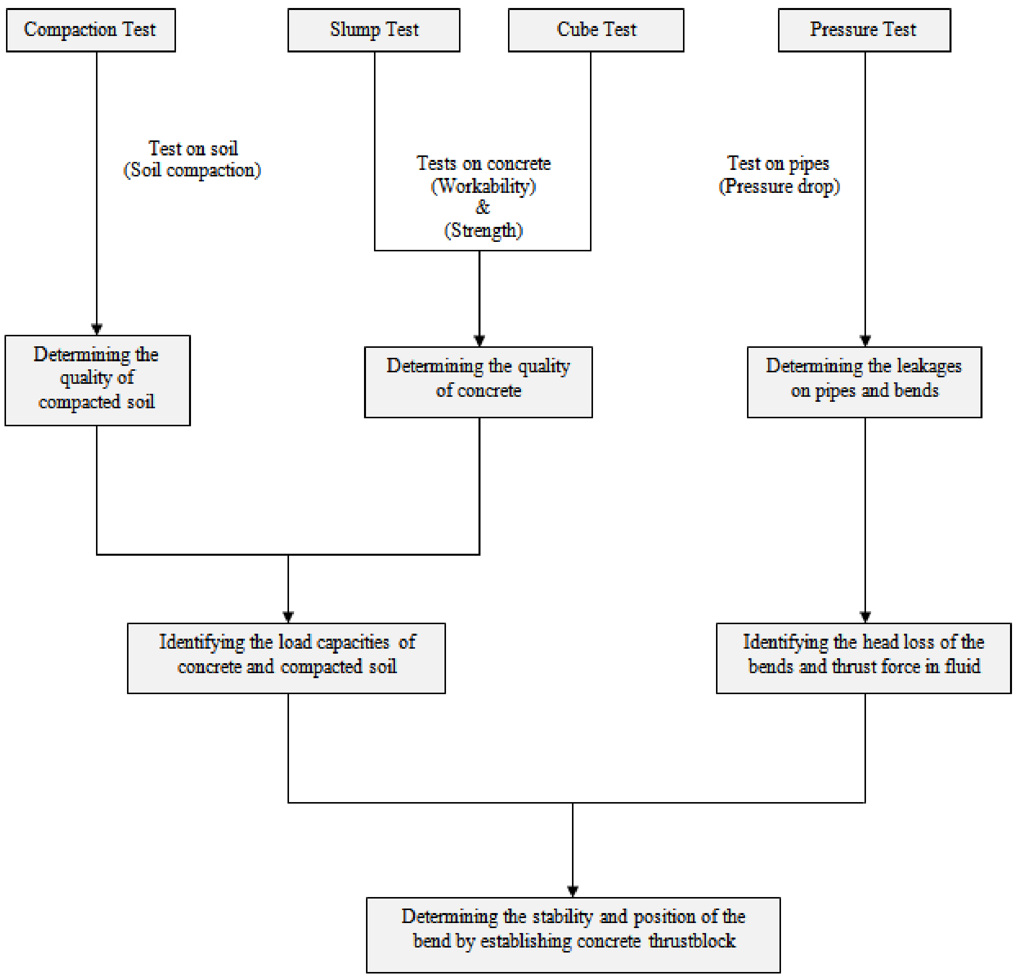
II. Methodology

According to the size of the population (number of people) ofselected area, the diameter of pipes and bends is identified.

According to the coordinates of selected bending path (between two chainages), the bend angleis identified.

Vertical and horizontal placement of the bends is directly given by trench parameters (bedding, covering, surrounding).

The following chart denotes the whole process of how to identify the optimum path and the position of the bend by considering tests: compaction test, slump test, cube test, pressure test.



III. Results And Discussion

a. Examples for identifying the pipe diameter, bend angle and trench parameters.

Let take the size of the population be 70.
According to the **developed algorithms** and **codes**, pipe diameter should be **63 mm**.

Population is the basic factor when considering the pipe diameter for relevant area.

The following figure shows the sketch of how to evaluate the bend angle using coordinates.

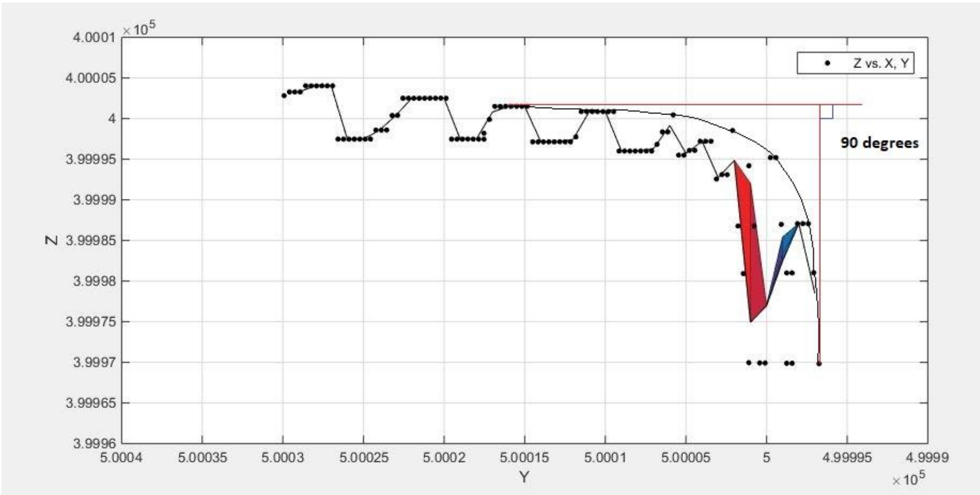


Figure 1: Sketch of identifying the bend angle using coordinates.

The solution for the bend angle ofabove bending path should be **90^0**.

Coordinates should be taken to determine the bending angle correctly.

Let take the pipe diameter be 63 mm.
According to the **developed algorithms** and **codes**,

Trench parameters:

(Vertical placement of bend)
Covering →**1000 mm**
Bedding
Thickness of quarry dust (Top layer & bottom layer) →**100 mm**

(Horizontal placement of bend)
Surrounding →**300 mm**

Sand is much better than quarry dust for bedding. Because there is a high possibility to pass the compaction test since sand
has a higher density.But sand cannot be applied alone due to its high cost. Therefore best alternative material should be
quarry dust.

b. All mathematical relationships by compaction test, slump test, cube test and pressure test.

The following constraints denote the derived mathematical relationships in tests.

Compaction test → Degree of compaction = Dry soil density / MDD [4]
DOC = [Wet soil density / 1+ (0.01x OMC)] / MDD ≥0.98 } (1)

Slump test →**100mm ≤** l (slump) **≤ 150mm**
Water / Cement **≤ 0.5** } (2)

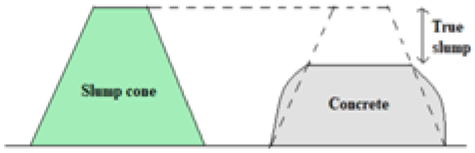


Figure 2: Slump distance of concrete.

Cube test →

Table 1: Ranges for strength of concrete according to number of days.

Days	Range of strength
3	**18Nm^{-2}** ≤ E (Strength of concrete) ≤ **20Nm^{-2}**
7	**23Nm^{-2}** ≤ E (Strength of concrete) ≤ **27Nm^{-2}**

} (3)

Pressure test →**0** ≤ K (Coefficient of head loss) ≤ **0.5**
P = 2σt / (d-t)
(P - Test pressure in MPa / σ - Induced stress (36 MPa) / t - Wall thickness /
d - Mean outside diameter)
[P / 600 MPa] ≥ **4.3** } (4)

Table 2: Ranges for wall thickness (t) of pipes according to pipediameter.

Pipe diameter	Range of wallthickness
63mm	**2.3 mm** ≤ t ≤ **3.0 mm**
90mm	**3.1 mm** ≤ t ≤ **3.7 mm**
110mm	**3.8 mm** ≤ t ≤ **4.4 mm**
160mm	**5.5 mm** ≤ t ≤ **6.8 mm**
225mm	**7.8 mm** ≤ t ≤ **8.6 mm**

Head loss decreases according to the size of bend angle (90^0> 45^0> 22 ½^0> 11 ¼^0).

By**(1)**, **(2)** and**(3)**,
Identification of total load capacity on concrete block:

$$\rho vg + 1.3(MDD)Vg$$

(ρ - Density of concrete/ MDD - Density of compacted soil/ V, v - Volume of compacted soil and concrete)

By **(4)**,
Identification of thrust force in fluid:

$$2PA\sin(\beta/2)$$

(P - Working pressure/ A - Cross sectional area of pipe/ β - Bend angle)

Then,

Determination of the stability of bend:

$$\frac{\rho vg + 1.3(MDD)Vg}{2PAsin(\beta/2)} \geq 1.4$$

c. Defining a total **safety factor** value for bends and **Numbering Method** is given below.

Total safety factor = $\left|\frac{\text{Dry density}}{\text{Maximum dry density}}\right| + \left|\frac{2 \times \text{Induced stress} \times \text{Wall thickness}}{(\text{Diameter} - \text{Wall thickness})}\right| + \left|\frac{\text{Load capacity of (concrete + soil)}}{\text{Thrust force}}\right|$

$$= \left|\frac{\frac{\text{Wet soil density}}{1 + (0.01 \times OMC)}}{MDD}\right| + \left|\frac{2\sigma t}{(d-t)}\right| + \left|\frac{\rho vg + 1.3(MDD)Vg}{2PAsin(\beta/2)}\right|$$

The boundary value of total safety factor is defined by combining allthe minimum values of each set in mathematical model.

Min$\{|((\text{Wet soil density})/(1 + (0.01 \times OMC)))/MDD|\}$= **0.98**
Min$\{|((2\sigma t)/((d - t)))|\}$= **4.3**
Min$\{|((\rho vg + 1.3(MDD)Vg)/(2PAsin(\beta/2)))|\}$= **1.4**

Therefore the lower bound of the value of total safety factor is **6.68**.

Numbering Method:
15 ≤ Safety factor→ (**A_1- A_4**)
11 ≤ Safety factor < 15→ (**B_1- B_4**)
6.68 ≤ Safety factor < 11→ (**C_1- C_4**)

Example:

If Pipe diameter = 63 mm/Bending angle = 45 degrees/ Wall thickness = 4 mm/ Dry density of soil = 1980 kgm^{-3}/
MDD of soil = 1985 kgm-3/ Length and Height of thrust block = 500 mm;

Total value of safety factor = **11.32**
By applying Numbering Method,
Number of safety factor is **B_4**.

IV. Conclusions

1. We should always think about the safety and durability of bends when we are applying bends in trenches and doing specific tests. Because safety depends on the quality of applied bends as well as used tests.
2. Total safety factor value for bends mainly depends on MDD (lab tested value), dry density, bending angle, wall thickness, pipe diameter, length and height of concrete thrust block.
3. Basic solutions of developed bend application are pipe diameter, trench parameters, bending angle, wall thickness, weight of concrete thrust block and compacted soil and safety factor.
4. **Numbering Method** - According to the performance of the bends safety factor can be categorized as A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4, C_1, C_2, C_3, C_4.

If 6.68 ≤ Safety factor < 11, then bend has a fair performance (C_1→C_4).
If 11 ≤ Safety factor < 15, then bend has a good performance (B_1→B_4).
If 15 ≤ Safety factor then bend has an excellent performance (A_1→A_4).

References

[1]. AWWA Principles and Practices of Water Supply Operations,Introduction to Water Distribution, Vol. (3).
[2]. Soilhttps://www.researchgate.net/publication/227557214_Soil_Definition_Function_and_Utilization_of_Soil (accessed Jan 16, 2019).
[3]. Geotechnical Training Manual No 7 Pipe Bedding and Backfill United States Department of the Interior Bureau of Reclamation Technical https://www.coursehero.com/file/31440926/pipebedpdf/ (accessed Jan 16, 2019).

[4]. https://www.scribd.com/document/320979765/CIVL354-Notes-1-Soil-Compaction (accessed Jan 16, 2019).
[5]. Silva DPHHPN, Lanel GHJ, Perera MTM. Integer Quadratic Programming (IQP) Model for Cut Order. International Organization of Scientific Research-Journal of Mathematics (IOSR-JM) [Internet]. 2017;13(2):76-80.

Dayan K.P.T. " Identifying the Optimum Path and the Positions of the Bends in PVC and DI Pipes in Underground Water Lines.." IOSR Journal of Mathematics (IOSR-JM) 15.2 (2019): 56-61