ECONOMIC EVALUATION OF PIPELINES (CASE STUDY)

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ABSTRACT

The need for safety factors arises mainly from uncertainties. These uncertainties are due to causes ranging from the pipe manufacturer to the pipe installation conditions. Standards for each pipe product may list recommended safety. Also, manufactures often recommend certain safety factors for their products. The design engineer should be aware of these differences when comparing products and should always have the option of requiring a safety factor that is different from the recommended value. The engineer should be very cautious in utilizing safety factors that are lower than those recommended by national standards or by the manufacturer.

The broadly used of pipe material with long lengths, with certain compacted soil and loading conditions have been utilized in the present work to analyze the way to measure the intrusion into safety factors.

The analysis found that intrusion percent into safety zone can be measured throughout portion of each of: contributory from wall yield strength provided by manufacturer, abuse from the one who fix the installation procedures and design provided by designer.

Keywords: Buried pipes, beam bending, Performance, Performance limits.

INTRODUCTION

Projects of buried pipes for water transmission and distribution considered to be the highest expected return, and appears to be the best investment alternative. There is risk – portion of a project that cannot be eliminated. But there is a specific risk – portion of a project that can be eliminated by reducing violation to safety factors.

The paper will commence with a short review of the history of mechanics of buried pipes. From this will be identified the ideal characteristics for the influence of violating of safety zone on the stability of pipes, causing damage and costs associated with.

The allowable total stress or strain is equal to the failure stress or strain reduced by a safety factor. The total working stress/strain must be equal to or less than the allowable stress/strain. Stresses due to internal pressure and external loads are evaluated separately.

Longitudinal mechanics of buried pipes is the analysis of longitudinal deformations compared to performance limits of deformation. One excessive deformation is fracture for which corresponding strain limits can be identified. If the pipe changes length enough to shear off appurtenances or to allow leakage of couplings, deformation is excessive and corresponding strain limits can be identified. If the strains can be evaluated, then corresponding stresses can be used as alternative bases for design, one of the principal causes of longitudinal stress (strain) is beam bending, which causes flexural stresses. Typical causes of beam bending are:

- Placement of pipe sections on supports,
- Non-uniform settlement of the bedding,
- Side-hill soil creep or landslide, and
- Massive soil movement or settlement.

In complex phenomenon as the soil-structure interaction of buried pipes, the mean targets for all pipes are optimum flow and minimum stresses in pipes and between the pipes and the materials they are buried. In the case of buried pipes, forces are statically indeterminate, and are regularly indeterminable because the soil is not uniform.

More common requirements of installation are by omitting precise details that vary in individual installations, with some safety aspects of pipeline constructions.

The construction of a pipeline depends on many controlling factors, including pipe materials, trench depth, topography, soil conditions and operating conditions. The properties of the soil bedding excavated and the soil used as backfill in the pipe zone are particularly important import, how the pipe is handled and installed can have huge effects on its external load-carrying capacity and can be a controlling factor in the design of the pipe. How the pipe supports the loads from handling, soil cover, and water must be determined when the pipe installation is designed.

The degree and uniformity of bedding support can have a substantial influence on the required pipe strength, if the bottom is brought to be grade with material in which all stones and hard lumps have been removed. This bedding material should be firm, and uniform along the pipe. Provide bell holes in pipe bedding, no larger than necessary, in order to ensure uniform pipe support.

Stress design needs a complete knowledge of Performance and Performance limit. Performance in soil-structure interaction is function of internal, external and diametric loads, geometry and properties of materials.

Performance limit for a buried pipe is basically a deformation rather than a stress. In some cases it is possible to relate a deformation limit to a stress (such as the stress at which a crack opens), but such a relationship only accommodates the designer for whom the stress theory of failure is familiar. Actuality, performance limit is that deformation further than the pipe-soil system could function the way it was planned. The performance limit could be a deformation in the soil, such as a dip or hump or crack in the soil surface over the pipe; both of dip or hump depends on the relative settlement of the soil over the pipe and the soil on either side. If performance limit is ring deflection at the elastic limit modulus of elasticity E is pertinent, yield strength is not pertinent.

STUDY APPROACH

It is the objective of the present work to demonstrate the influence of using great margin of safety zone for buried pipes on the structural stability. Pipe investigated in this paper is manufactured using wall strength of 552 (kN/m^2). Those pipes meet the requirements of such international standards as ASTM, AWWA, DIN, BS, and ISO. Pipe's properties complying with those various national and international standards are based on long term data interpolated to 50 years.

To investigate the contributory of violation of safety zone, a specified compacted soil with no organics or large rocks have been used in the present paper. The ground water level was assumed to be at the ground surface. Pipe should be embedded in non-cohesive backfill materials such as medium sized gravel, crushed rock, sand, or sand/gravel mixtures. In the present work, the backfill was assumed to be compacted sand not saturated with water table.

Regarding the surface loading, unit weight of dry soil, weight per unit length, and unit weight of liquid inside the pipe utilized in this paper, Table (1) presents the values of all these variables and pipe diameter, and pipe mechanical properties, as well. The dual wheels were separated by 2 m.

The impact of the composite factors reflect the risk of violation of safety factor of water transmission and distribution project carried out by any organization was investigated in this paper by calculating the values of such parameters.

Table (1): Values of the different variables in the present study

No.	Variable	Value
1	Unit weight of dry soil (N/m^3)	19000
2	Weight per unit length (N/m)	2918
3	Unit weight of liquid (N/m^3)	6596
4	Live Load (Traffic) ,(kN)	72
5	Nominal Diameter (m)	2200
6	Length of the pipe (m)	13
7	Height of soil cover (m)	1.85
8	Total Wall Thickness (m):	0.15
9	Mechanical Properties of pipe: Yield Tensile Strength of pipe wall (kN/m^2) Design Stress (kN/m^2)	 689.5 344.8

Definitions and/or formulas of those selected parameters mentioned above are presented in the next sections.

If a pipe that is initially straight is bent into a circular arc of radius R, longitudinal strains develop in the outside fibers, Figure (1). If R is too short, the pipe buckles; i.e., crumples at a plastic hinge. Strain is a better basis for analysis than stress. In the following, both stresses are analyzed because yield stress is performance limit in some cases. Due to beam bending, longitudinal strain and stress (elastic theory) are:

$$\varepsilon = r/R \qquad \text{and} \qquad \sigma = Er/R \tag{1}$$

where ε is the maximum longitudinal strain tension outside of bend and compression inside, σ is maximum longitudinal stress, r is outside radius of the pipe cross section, R is longitudinal radius of the pipe axis on the bend, and E is modulus of elasticity:

$$E = \frac{\sigma}{\varepsilon} = \frac{Force/Area}{Elongation/Length}$$

in another way:

$$\sigma_A = \sigma_f / SF \;\; , \; \varepsilon_A = \varepsilon_f / SF$$

where:

σ_A = allowable stress
σ_f = failure stress
ε_A = allowable strain
ε_f = failure strain
SF = Safety factor

Longitudinal bending is caused by soil movement, heavy surface loads, differential subgrade soil settlement, landslides, and non-uniform bedding. Non-uniform bedding is inevitable despite specifications calling for uniform bedding.

Under, soil loads + weight of the pipe + contents, the pipe deflects and causes longitudinal stress. That is why manufacturers of reinforced pipes provide longitudinal reinforcement and limit the lengths of pipe sections. A bend in the pipe causes a moment, M, for which longitudinal stress is:

$$\sigma = Mr/I \tag{2}$$

where σ is longitudinal stress, r is outside radius of the pipe cross section, I is πtr^3 is moment of inertia of plain pipe cross section, t is wall thickness of plain pipe, M is moment at some point along the pipe which acts as a beam.

Moment M can be analyzed from the loads and supports on a pipe. The supports are intermittent hard spots along the pipe. If bedding were truly uniform, the pipe could not deflect as a beam. However, bedding is never uniform, and so there is always some deflection and some M. The maximum M from beam analysis is substituted into Equation (2). For design, the maximum combined longitudinal stress must be less than the strength reduced by a safety factor.

If reactions are only at the ends of pipe sections or at midlength, the moment is maximum at midlength and may be found from the equation,

$$M/ wL^2 = 1/8 \tag{3}$$

If the maximum moment due to probable locations of reactions can be found, then maximum stress can be found from Equation (2), and requirements can be established for allowable length of pipe sections and their longitudinal strength. From the critical influence number, W/wL^2, maximum longitudinal stress can be calculated.

RESULTS AND CONCLUSION

The values of the selected assessment parameters mentioned above are calculated under the selected conditions. The results of the conducted computations are the safety zone is from 345 to 690 (kN/m^2) (which is between stress design and yield strength of pipe wall), weight per unit length of tank is the tank full of water, plus prismatic soil load on top. As the tank is a simply supported beam, including live load, the longitudinal stress in the bottom at midspan is 528 (kN/m^2).

If the constructor had a history of problems with hard spots, a probability might be developed. Without such a history, probability can only be assumed and varied to determine the effect of hard spots on the probability of a leak. This could serve to evaluate violation of the constructor's hard spots into the risk zone. Or from the history (track record) of the constructor, suppose that hard spot shows up in the bedding, Figure (2), and leveled the pipe at the ends thereby forcing the pipe to act as a simply supported beam with no bedding, Figure (3). There was no compaction under the haunches. Had a bedding reduced stresses to 40% percent of the simply supported beam stresses, the maximum stress in the pipe would be (40%)(528) equal to 211 (kN/m^2). The violation is (528-211)/(689 -211) equal to 66%.

Producer supplied pipe with wall strength of 552(kN/m^2) according to leak tests not 689 (kN/m^2) as producer's recommendation. The violation is (689-552)/(689- 345) equal to 40%.

Designer specified compacted soil with no organics or large rocks. The tank was designed for 40% of simply supported beam stresses assuming that the bedding would provide some support. But the beam was simply supported. Therefore, design violation is (528-345)/(689- 345) equal to 53%.

At the commencement, we identified the violation percent into the risk zone equal to equal 160%. Limited to the conditions investigated in the present study and based on the obtained results, the following conclusions can be drawn:

1. The constructor violation amounts about 66/160 equal to 42%. This amount reducing resisting capability of the pipe because there was no compaction and create a hard spot which force pipe to act as a simple beam.
2. Pipe manufacturer are expected to provide adequate longitudinal pipe strength for ordinary buried pipe conditions including handling, shipping, and installing, but violation percent about 40/160 equal to 25%.
3. The pipeline designer does not expect to investigate longitudinal stresses except for adverse conditions such as beam action of a buried pipeline supported hard spot. The pipeline designer accepts the manufacturer's recommendation for lifting, stacking, stabbing of joints, etc., so longitudinal stresses will not be excessive, but violation percent about 53/160 equal to 33%.

Limited to the conditions investigated in the present study and based on the obtained results, the following conclusions can be drawn:

- Future safety factors should include possibility of failure, and the cost of failure in addition to risk and liability.
- Management of municipal should and control an effective way so not to lose revenue and incur unnecessary costs, by measuring relative responsibilities between manufacturer, installer and designer.

- Designers must be alert for imperfection of construction, overloads, and flawed materials.
- Engineers design should take into consideration some assorted concerns, such as construction loads, installation techniques and soil availability.
- Municipal must not allow contractors have records for intrusion safety sector.
- Information upon which council directs legal proceedings must come from the engineer.
- We should carry out researches projects on field inspection tools, and mechanical behavior for pipelines construction.
- Designers should measure the Effectiveness of performance against many criteria, flexibility, lack of complaints, efficiency of performance within line.

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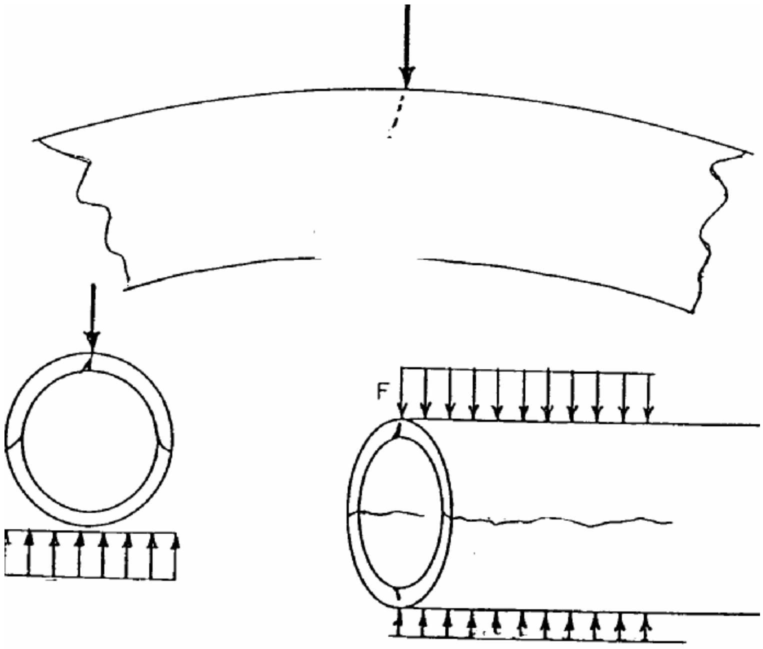

Figure (1) Bending of a pipe

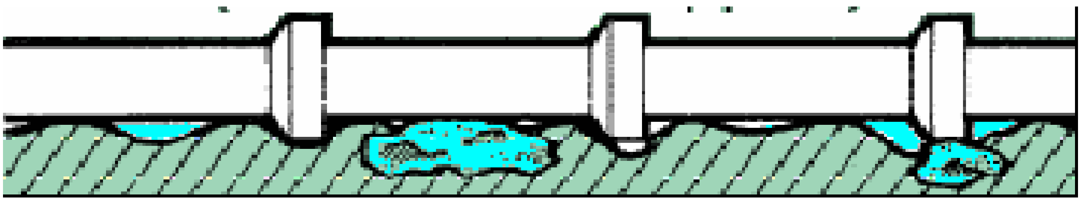

Figure (2) Non uniform support

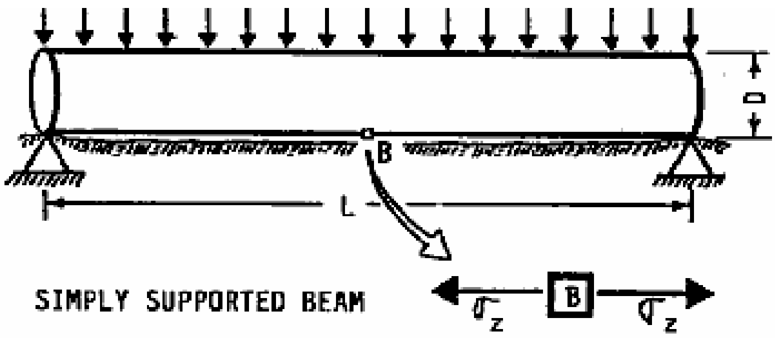

Figure (3) Simply supported beam