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CALCULATION OF BUCKLING PIPE FOR PIPE SIZE 10", 40" AND 56" CROSSING AT NUCLEAR POWER PLANT

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ABSTRACT
The actually buried pipe crossing in the project of NPP (Nuclear Power Plant) installation to be found the self problem for installation, especially if the crossing will be subjected to loads of vehicle traffics and weight of soil, this pipe shall be make sure is not buckling during operation with deflection calculation shall be lest then 1% ratio between radius of pipe.

Keyword : buried pipe, buckling, deflection

ABSTRAK
Pada proyek pekerjaan instalasi PLTN (Pembangkit Listrik Tenaga Nuklir) di lapangan sering ditemukan permasalahan instalasi silang pipa benam khususnya persilangan dengan jalan yang memuat beban arus kendaraan dan beban berat tanah. Kalkulasi ini bertujuan untuk memastikan tidak terjadi buckling pada pipa selama operasi yang tidak melebihi dari 1% dibandingkan dengan radius pipa.

Kata kunci : pipa benam, tekuk, pergeseran.

1. INTRODUCTION

To calculation is to compare anticipated performance with desired performance within performance limits. For cast iron soil pipe, the structural performance limit is leakage. Excessive deformation causes breaks and leaks, but excessive deformation of cast iron soil pipe is directly related to stress, so stress determines basic structural performance. Anticipated (analyzed) stress must be within the stress limit called strength. Because of interaction between the pipe and the soil in which it is buried, stress analysis is complicated. Available now are computerized mathematical techniques of analysis such as the finite element method. But such techniques are generally better than the installations they are designed to model. It is not yet practical to bury a soil pipe in soil which has properties and boundary conditions as precisely known and as precisely controlled as assumed by the analysis.

Consequently, calculation is based on simplifying assumptions of soil loads which when analyzed give the worst stresses. These stresses are compared to strengths which have been reduced by a reasonable safety factor.

Since strength is the maximum stress caused by a test load on the pipe at failure, why not equate the worst stress to the test strength in order to provide a design equation that relates anticipated soil pressure to test load. Calculation then becomes simply a process of comparing the anticipated soil pressure to an equivalent pipe test load which has been reduced by a safety factor. The soil pressure is the vertical soil pressure P acting down on the pipe. The test load (strength) is a laboratory test to failure of the pipe.

Within the parameters of established trench widths and installation conditions described in this cacIculation, cast iron soil pipe may be buried to depths up to 1,000 feet (0,0254 m), depend on class of pipe,diameter, and installation condition. Cast iron soil pipe has those properties desirable for deep burial; beam strength, pipe stiffness, and resistance to stress.

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By creating a compacted soil arch over the pipe packed in a compressible soil envelope, the allowable depth of burial can be doubled. Calculation on soil load assumptions that give the worst stress is more practical than computerized analysis, which required known soil properties and boundary conditions, none of which are readily available or controllable on most projects.

In using structural design information on underground cast iron soil pipe installations, it must be recognized that there are variations in soil characteristics and construction practices throughout the country. This data is presented as convenient reference. Effective design requires conformity with specific construction practices and recognition that the computations are based on calculation regarding earth loads, truckloads, trench depths, and other factors.

2. TEORITICAL

When pipes are buried, many forces affect them. The following are the main forces expected to affect buried pipes:

2.1 Loads due to Back fill

Back fill load on a pipe depends on:
- Trench width
- Depth of excavation
- Unit weight of the fill material
- Frictional characteristics of the backfill.

These factors are formulated in the following formula, from ref. 3 we find :

$$Wd = 9.8\, C_d * \rho * B_d^2 \quad \text{................ (1)}$$

where :

Wd = load on buried pipe as due to backfill (Newton per linear meter)

Cd = Coefficient based on the type of backfill and ratio of trench depth to width.

ρ = Density of backfill, 1520 kg/m3

Bd = Width of trench at top of the pipe, assumed = 2*OD (m)

OD = Outside pipe diameter

H = Depth of excavation (m)

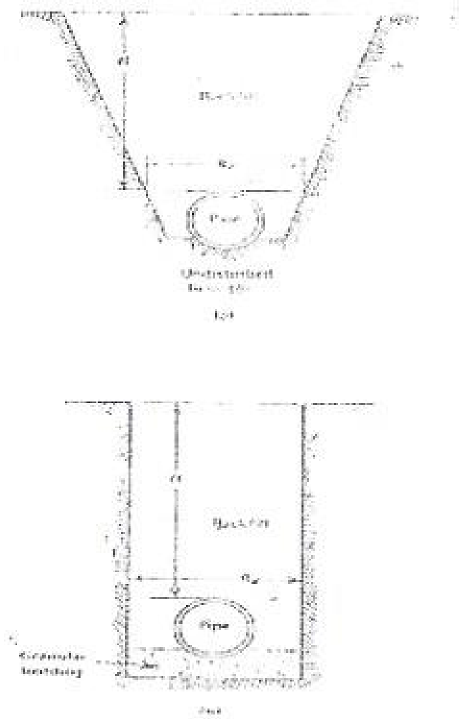

Figure 2.1
Condition of soil over the pipe

$$C_d = \frac{1 - e^{-2kf\frac{H}{B_d}}}{2kf} \quad \text{............. (2)}$$

where :

k : ratio between active internal pressure and external vertical pressure

f : friction coefficient between backfill material and trench vertical sides

kf value are given in the following table.

Table 2. 1 : Values of kf

Values of k*f for different backfill types:

Backfill Type	k*f
Cohesionless granular material	0.192
Sand and Gravel	0.165
Saturated topsoil (other than clay)	0.150
Clay	0.130
Saturated clay	0.11

Kf assumed = 0.11 (saturated clay)

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2.2 Loads due to Truck

Wheel loads from trucks and vehicles transmit live loads to buried sewer lines. When the sewer is deep, only a small portion of the load is transmitted to the sewers. Equations to compute live loads are very complex that's why designers pre-calculated data as illustrated by Tables. Table gives the highway truck loads transmitted to buried circular pipe in kN/m.

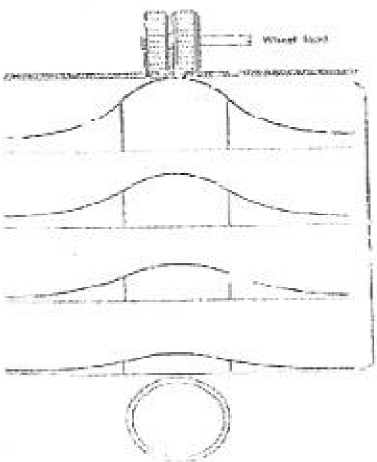

Figure 2.2
Rear load of truck transmitted to buried pipe

The information needed are:
Pipe diameter (d).
Height of fill (H) above pipe (m).

Table 2.2 : Load vs Height of piling

Pipe Diameter, millimetres	Height of Fill H Above Pipe (metres) 0.15	0.20	0.46	0.61	0.76	0.91	1.07	1.22	1.52	1.83	
305	70.8	39.9	22.5	13.9	8.4	5.3	4.6	3.5	2.5	0.7	305
381	86.4	48.5	27.3	17.0	10.2	6.4	5.2	4.2	3.0	0.8	381
457		57.3	32.1	20.0	12.0	7.6	6.6	5.0	3.5	1.0	457
533		65.7	36.9	23.1	13.9	8.7	7.6	5.7	4.1	1.1	533
610			41.7	26.1	15.7	9.9	8.6	6.5	4.6	1.3	610
686			45.2	29.2	17.5	11.1	9.6	7.2	5.2	1.4	686
762				32.2	19.4	12.2	10.7	8.0	5.7	1.6	762
838				34.6	21.2	13.4	11.7	8.7	6.2	1.7	838
914					23.1	14.5	12.7	9.5	6.8	1.9	914
1 067					24.5	16.9	14.7	11.0	7.8	2.1	1 067
1 219						17.8	16.7	12.5	8.9	2.5	1 219
1 372							17.3	14.0	10.0	2.7	1 372
1 524								14.5	11.1	3.0	1 524
1 676									12.1	3.3	1 676
1 829									12.5	3.6	1 829
1 981										3.9	1 981
2 134										4.0	2 134

Note: The load is based on (71.17 kN dual-tire wheel load).

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If the cover fill is less than (1m) the value obtained from table should be multiplied by an impact factor obtained from next table. [Ref. 3]

Table 3 : Impact Factor

Height of Cover H	Impact Factor
0 to 0.30 m	1.3
0.31 m to 0.60 m	1.2
0.61 m to 0.90 m	1.1
0.91 m and greater	1.0

3. BUCKLING CALCULATION

Buckling of pipe can be calculate based on the loads of subject to the pipe surface. The buckling of pipe while the deflection of the pipe during subject loaded ratio of pipe radius more than 1%.

Actual deflection of the pipe (d) can be calculate following formula , [Ref. 2]:

$$d = \frac{0.108x[WxR^3]}{[ExI]} \quad \text{.....................(4)}$$

$$W = L(w_{backfill} + w_{truck}) \quad \text{..............(5)}$$

Where:

W = Total Loads (kg/m)
$w_{bacfill}$ = Weight of Soil (kg/m)
w_{truck} = Average of Traffic Weight (kg)
R = Radius of Pipe (cm)
E = Elastic Modulus of Pipe (Kg/cm-2)
I = Inertia of Pipe (cm-4)
L = Length of Pipe Crossing (m) = 6 m

BUCKLING CALCULATION ON PIPE CROSSING OF SIZE 10"

Data:

Pipe data:

D_O = 273.05 mm = 0.27305 m
R = 136.525 mm = 13.6525 cm
E = 2.07379E+6 Kg/cm-2
I = 6690 cm-4

Soil Data

H = 842 mm = 0.842 m
ρ = 1528 Kg/m-3

Truck Data:

Total truck load is assumed 310.022 ton.

$w_{bacfill}$ = 595.71 kg/m
w_{truck} = 4648.84 kg/m

Taken from Table 2 for Rear single wheel load = 0.2*Total Truck load.
Impact factor for height of cover 0.842 m = 1.1 (Table 3)

Calculation for 6 m pipe crossing:

W = 6*(595.71 + 5113.72) = 34256.60 kg

Actual Deflection:

$$d = \frac{0.108x[WxR^3]}{[ExI]} \quad \text{...................(4)}$$

$$d = \frac{0.108x[34256.60x13.6525^3]}{[2073790x6690]}$$

d = 6.78E-04 cm

Buckling Ratio (r) :

$$r = \frac{d}{R}x100\% \leq 1\% \quad \text{..............(6)}$$

$$r = \frac{6.78e-4}{13.6525}x100\%$$

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$r = 4.97 \times 10^{-3}\,\%$

Therefore the ratio lest then 1% than the pipe is <u>not buckling</u> during subject to weight of soil and traffic vehicle loads.

BUCKLING CALCULATION ON PIPE CROSSING OF SIZE 40"

Data:

Pipe data:

D_O =1016 mm = 1.016 m

R =508 mm = 50.8 cm

E =2.07379E+6 Kg/cm-2

I = 635381 cm-4

Soil Data

H =900 mm = 0.90 m

ρ = 1528 Kg/m-3

Truck Data:

Total truck load is assumed 310.022 ton.

$w_{bacfill}$ =2662.58 kg/m

w_{truck} =4648.84 kg/m

Taken from Table 2 for Rear single wheel load = 0.2*Total Truck load.

Impact factor for height of cover 0.9 m = 1.1 (Table 3)

L =Length of Pipe Crossing (m) = 6 m

Calculation for 6 m pipe crossing:

W =6*(2662.58 +16306.00) = 113811.52 kg

Actual Deflection :

$$d = \frac{0.108x[113811.52x50.8^3]}{[2073790x635381]}$$

d = 1.22E-03 cm

Buckling Ratio (r) :

$$r = \frac{d}{R}x100\% \leq 1\%$$

$$r = \frac{1.22e-3}{50.8}x100\%$$

$r = 2.41 \times 10^{-3}\,\%$

Therefore the ratio less than 1% the pipe is <u>not buckling</u> during subject to weight of soil and traffic vehicle loads.

BUCKLING CALCULATION ON PIPE CROSSING OF SIZE 56"

Data:

Pipe data:

D_O =1422.4 mm = 1.4224 m

R =711.2 mm = 71.12 cm

E =2.07379E+6 Kg/cm-2

I = 2793114 cm-4

Soil Data

H =900 mm = 0.90 m

ρ = 1528 Kg/m-3

Truck Data:

Total truck load is assumed 310.022 ton.

$w_{bacfill}$ = 3779.13 kg/m

w_{truck} =4648.84 kg/m

Taken from Table 2 for Rear single wheel load = 0.2*Total Truck load.

Impact factor for height of cover 0.9 m = 1.1 (Table 3)

L =Length of Pipe Crossing (m) = 6 m

Calculation for 6 m pipe crossing:

W =6*(3779.13 +16306.00) = 120510.82 kg

Actual Deflection :

$$d = \frac{0.108x[120510.82x71.12^3]}{[2073790x2793114]}$$

$d = 8.08 \times 10^{-4}$ cm

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Buckling Ratio (r) :

$$r = \frac{d}{R} x100\% \leq 1\%$$

$$r = \frac{8.08e-4}{71.12} x100\%$$

$$r = 1.14 \times 10^{-3}\ \%$$

Therefore the ratio less than 1% the pipe is not buckling during subject to weight of soil and traffic vehicle loads.

4. SUMMARY

The result of calculation it can be summarized as follows :

1. The actual deflection of pipe shall depend on the depth of buried pipe, some of rear truck subject to pipe crossing and type of soil.
2. Buckling to be occur when the ratio of actual deflection with radius of pipe more than 1 %.
3. Buckling calculation shall be considered from buried pipe calculation, especially **nuclear power plant engineering and construction.**
4. Ratio deflection with 1 % **is more strick for nuclear power plant** than others plant system with 5%.

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