Effect of Seismic Forces on Underground Pipeline

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ABSTRACT

Depending upon the type of structure, the various types of forces are acted upon and its stability is checked for imposed loads. Much of the concentration is on the stability of frame structures like buildings. However, other structures like underground pipeline, tunnel, culverts, etc. are equally important. The aim of this dissertation is to study the effect of the seismic forces on the underground water pipeline subjected to fluid pressure, earth fill pressure or surcharge, uplift forces, lateral side pressure, etc. The underground pipeline is analyzing manually. Later on, the pipeline is modelled and analyze for presence and absence of lateral seismic forces and comparative study is shown in this report. Out of the two cases, the exterior and interior node location along the circumference is studied. Similarly, plate elements are studied for stresses, on the basis of study the conclusions are drawn.

Keywords: Pipe, Node Displacement, Centre Stress, Corner Stresses

1. INTRODUCTION

1.1 Aim

The aim of this dissertation is to effect of seismic forces on underground pipeline.

1.2 Objective

- To Study different forces acting on pipeline.
- To study the behavior of soil around the water pipeline and hoop stresses.
- To study of analysis of seismic forces on pipeline.
- Importance of water pipeline.
- To study the seismic resistance of concrete pipeline.
- To develop analytical model with seismic forces and without seismic forces using STAAD-Pro.
- Comparing the results of analyzed model with seismic forces and without seismic forces.

1.3 Scope

Use of underground pipeline leads to further advantages such as low losses due to evapotranspiration, infiltration, contamination free quality of water and it is possible to provide flow under pressure, etc. Though as pipeline is underground it is subjected various stresses due to soil acting as surcharge, loading due to various traffic operations, temperature changes, etc. and hence it should be resistant to all the stresses coming over it during its useful lifetime. Generally, water supply pipeline mains are designed for design period of 30 years.

Supply of water, gases, oil, etc. to the society plays very important role in social and economic growth of any country. Supply of water to the society is one of the major tasks. Water can be supplied society by various ways such as through open channel, buried pipelines, etc. open channel conveyance of water is possible for irrigation water to the field by means of canals. Though leads to large amount of losses due to direct exposure to the atmosphere. This deficiency can be overcome by means of water distribution through pipeline.

1.4 Need

Pipeline is the transportation of goods or material through a pipe. Water is essential factor in life. Earthquakes can cause extensive damage to buried water supply pipelines, resulting in major financial losses for water utility operators and lengthy disruption of an essential service for whole communities. Water is important factor of society, industries, and agricultural use etc. if water pipeline damaged then this is not good for above factor.

The purpose of this project is investigating parameters that affect response of buried pipelines due to high-frequency seismic excitations. The main focus of the study is on reinforced concrete pipelines. Water distribution systems are one of six broad categories of infrastructure grouped under the heading 'lifelines'. Together with electric power, gas and liquid fuels, telecommunications, transportation and wastewater facilities, they provide the basic services and resources upon which modern communities have come to rely, particularly in the urban context. Disruption of these lifelines through earthquake damage can therefore have a devastating impact, threatening life in the short term and a region's economic and social stability in the long term.

2. RESEARCH METHODOLOGY

2.1 Phase 1

- Aim, Objectives, Scope, Needs
- Detailed study of the standards specified for design of pipeline

2.2 Phase 2

- Start of experimental work
- Verification problem consideration
- Manual calculation of loading on pipeline for 2.5 m stretch

2.3 Phase 3

- Computational modelling and analysis of pipeline
- Comparative study
- Observation and remark
- Conclusion

3. DETAILED STUDY

Piping materials are generally divided into two groups; rigid and flexible. Concrete and steel pipelines are examples of rigid and flexible piping materials, respectively. Compared with steel concrete is an economical and durable material, widely used in water and wastewater networks. In this chapter first damage patterns of pipelines with respect to piping material and joints are described. Typical concrete and steel pipelines which are commonly used in water and waste water networks are described thereafter.

3.1 Different types of pipeline on the basis of material

- Cast iron (CI) pipes
- Steel pipes
- Concrete pipes
- Copper pipes
- Galvanized iron (GI) pipes
- Plastic or polythene or PVC pipes
- Asbestos pipes
- Polypropylenes (PRP) pipes

3.2 Concrete pipeline application

Steel reinforcement concrete pipeline (SRCP) has a product life at of 100 years or more .one of the best service lives of any pipe products. It is the low risk choice for the specific with a long history of reliability, no limits to weather exposure prior to installation and increasing strength over time. It is easy to join and install, self-heals and performs soundly above or below the water table.

Application

- Transverse culvert
- Storm water drainage
- Pressure and irrigation
- Pipe jacking and micro-tunneling

3.3 Different loads on pipeline and Load consideration

Stresses due to pressure generated by the flow (internal pressure). External pressure by the fluid if the pipe is submerged under water. External pressure generated by the weight of the earth and live loads on buried pipes. Loads due to thermal expansion, earthquakes.

3.4 Types of Loading

- Static load
- Live load
- Thermal load
- Bouncy forces
- Seismic forces
- Hoop stresses
- Water hammer pressure
- Uplift pressure

In the design of a concrete pipe an assessment shall be made of the following vertical loads: The static load at the level of the top of the pipe due to the fill material, The static load at the level of the top of the pipe due to loads superimposed on the fill material, and The internal static load due to the weight of water contained in the pipe.

3.4 Internal water Pressure or Static Pressure

The weight of water in a pipe running full generates an additional load; the equivalent external load on the pipe can be calculated from the following equation:

$$P_s = 9.81\left(\frac{3\pi}{4}\right)\left(\frac{d^4}{4}\right)$$

Where, W_w = equivalent water load in KN/m^2

d = Internal diameter of the pipe in m

Water hammer pressure

$$P_{h,max} = \frac{14.6}{\sqrt{1+\frac{Kd}{t}}} \times V$$

For concrete pipes K=0.1

$$\text{Total maximum internal pressure} = \text{Static Pressure} + \text{Water Hammer Pressure}$$

Due to this hoop stress and longitudinal stresses will develop.

a) Hoop stress will be, $\sigma = \frac{pd}{2t}$

b) Longitudinal stress will be, $\sigma = \frac{pd}{4t}$

3.5 Uplift Pressure:

An uplift pressure is any upward pressure applied to a structure that has the potential to raise it relative to its surroundings. Uplift forces can be a consequence of pressure from the ground below, surface water and so on.
Let U is the force that lifts the pipe. The pipe uplift equation is given by,

$$\sigma_p = \gamma(H + D)$$

3.6 Side Pressure Due to Compacted Fill:

Pipes are capable of using only the active earth pressures because they do not distort materially under vertical load and the sides of the pipe do not move outward enough to produce any appreciable passive pressure. It is safe to assume that active horizontal pressures about equal to those calculated by Rankine's formula may be considered to act against those portions of rigid pipe which project above the surface of the natural ground adjacent. This concept of active pressure acting against "rigid" conduits does not seem entirely reasonable, and it appears that a lateral pressure closer to the "at-rest" condition may be more realistic.

At Top level of pipe $\quad \text{Side Pressure} = K_a \gamma H$

At Bottom level of pipe $\quad \text{Side Pressure} = K_a \gamma (H + D)$

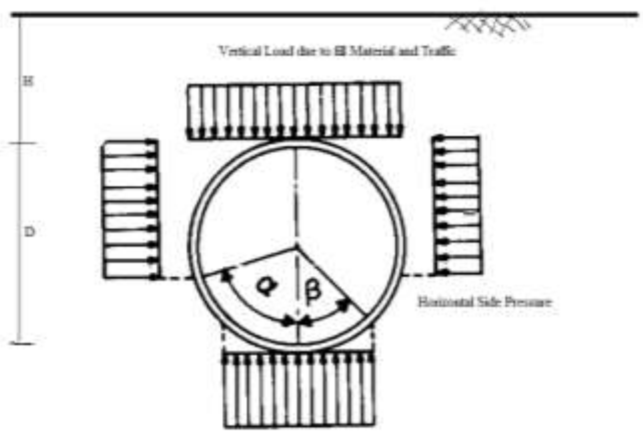

Fig. 4.1 Different load acting on underground pipeline

3.7 Effect of Backfill and Impact Load At Top of Pipe

In pipe line design, analyses of minimum soil cover required are essential to protect the integrity of the buried pipe under different loading and environmental conditions. Soil is the major component of a flexible buried pipe system. Soil protects the pipe by holding the pipe in shape and in alignment. The following are analyses of minimum soil covers required for protection against wheel loads, flotation, uplift, and frost.

3.8 Concrete pipelines

Concrete pipelines are designed for pressure flow systems and gravity flow systems. Pressure flow concrete pipe are used to transport and distribute potable water. A sewage system is mostly separated in two parts; sanitary sewers and storm sewers. Gravity-flow concrete pipelines are widely used in sewer systems but some sanitary sewers use pressurized lines since they usually are deeply buried

3.9 Steel pipelines

Steel pipelines have a variety of applications such as transport of water, wastewater, oil and gas but also for structural piling and supports. The steel pipelines are generally made in two types; welded steel pipelines or seamless steel pipelines. The seamless type is commonly used for high pressure applications such as gas transmission lines. Herein, welded water steel pipelines will be described. Steel water pipelines are typically manufactured in the size range from 100 mm to more than 3660 mm in diameter. There are commonly two methods for manufacturing water steel pipelines, as spiral seam pipelines and straight seam pipelines. Spiral seam pipelines are produced from coiled strips of steel through a continuous process.

3.10 Seismic Analysis of Buried Pipelines

Propagation of seismic waves in soil causes two types of deformations; 1) Axial deformation caused by the components that propagate along the pipeline axis and, 2) Bending deformation generated by the components of the waves that propagate in a direction perpendicular to the longitudinal axis. Different methods have been proposed for buried pipeline analysis from simple ones neglecting soil-pipe interaction to complicated Finite Element (FE) Models.

3.11 Seismic analyses of buried pipelines by neglecting soil-pipe interaction

Newmark presented a simplified method for calculating the pipe deformations due to wave propagation. In this method, it is assumed that the pipe follows the soil deformation without slippage and interaction. Therefore, it gives the upper bound estimate of the strains in the pipeline. When a wave propagates with the wave velocity c relative to the ground surface (apparent wave propagation velocity), along the longitudinal axis (x-axis) of the buried pipeline, the particle displacement of the soil is a function of ($x-ct$):i.e.h = f(x-ct)

3.12 Formulae for Calculation of Vertical Loads on Pipes Due to Fill Material (IS 783-1985)

3.12.1 Trench Condition

The pipe is laid in a narrow trench excavated in earth or rock (see Appendix B). the fill material the load which reaches the pipe is less than the weight of material and **1** above the pipe because of the friction between the fill: he sides of the trench. The frictional resistance diminishes with increase in trench width at the level of the top of the pipe. W, is calculated as follows:

$$W_e = C_t WB^2$$

Where C_t has the values given in IS 783-1985

3.12.2 Positive Projection Embankment Condition

The pipe is laid in a shallow excavation with its top projecting above the adjacent undisturbed foundation material. The vertical load transmitted to the pipe is usually greater than the load due to the weight of the fill material above the top of the pipe because settlement of the fill material adjacent to the pipe transfers additional load to the pipe by friction. It is an advantage therefore, to compact the fill material adjacent to the pipe to maximum density.

W*e* is calculated as follows:

$$We == C_e wD^2$$

3.12.3 Wide Trench Condition

The pipe is laid in a wide trench (see Appendix B). The frictional resistance between the fill material and the walls of the trench has less effect than in the case of an ordinary trench, and the installation conditions may vary between trench conditions and positive projection conditions. The lesser of the loads calculated assuming trench conditions projection conditions F shall be adopted Y when calculating minimum test.

We is calculated as follows:

$W_e = C_t wB^2$ for trench conditions, and

$W_e = C_e wD^2$ for positive projection conditions.

Where Ct has the values given in Fig. 4 and C, has the values given in Fig. 1.

3.12.4 Imperfect Trench Condition

The pipe is first laid under positive projection conditions (see Appendix B) and the fill material is placed and compacted to the designed height. A trench of width equal to the outside diameter of the pipe is then excavated in the compacted fill material directly over the pipe and to within 300 mm of the top of the pipe. This trench is then refilled with loose material such as straw, hay, leaves or brush, and left unconsolidated. The embankment is then completed and consolidated. The load transmitted to the pipe under these conditions is less than the load transmitted under positive projection conditions.

We is calculated as follows:

$$We = C_n WB^2$$

3.12.5 Negative Projection Embankment Condition

The pipe is laid in a narrow trench excavated in undisturbed earth or rock. The trench is loosely filled up to natural surface with fill material and the fill material is then built up to the designed height as shown in Fig.4.9. The load transmitted to the pipe under these conditions tends to be intermediate between the load transmitted under trench conditions and the load transmitted under positive projection conditions. A-5.2 We is calculated as follows:

$$W_e = C_n wB^2$$

4. Manual Pipeline Design for Pipeline Forces

For the design, modelling and Comparisons purpose following problem is considered as: Consider a reinforced concrete pipe lay under positive embankment condition.

Internal diameter of pipe (d) = 750 mm
Wall thickness or pipe thickness (t) = 40 mm
External diameter of pipe (D) = 750+2×40 = 830 mm
Unit weight of fill material (W) = 18 KN/m^3
Height of embankment fill over the top of pipe, H = 2.5m

Bedding and foundation material Positive embankment condition: Bedding Type A: Earth foundation
Velocity of water in pipe, V=3 m/s
Settlement ratio, r_s = 0.5 (for positive embankment condition)
Projection ratio, P = 0.7

Step 1: Calculation of Internal water pressure and hoop tension acting on pipeline

a) Internal water pressure or Static pressure

$$P_s = 9.81\left(\frac{3\pi}{4}\right)\left(\frac{d^2}{4}\right) \qquad P_s = 9.81\left(\frac{3\pi}{4}\right)\left(\frac{0.75^2}{4}\right) \qquad P_s = 3.25 \text{ KN/m2}$$

b) Water hammer pressure

$$P_{h,max} = \frac{14.6}{\sqrt{1+\frac{Kd}{t}}} \times V$$

For concrete pipes K=0.1

$$P_{h,max} = \frac{14.6}{\sqrt{1+\frac{0.1\times 0.75}{0.04}}}\times 3 \qquad P_{h,max} = 25.84 KN/m^2$$

c) Total internal pressure acting on pipe

$$P = P_s + P_h \qquad P = 29.09\ KN/m^2$$

d) Hoop stress

$$\sigma = \frac{pd}{2t} \qquad \sigma = \frac{29.09\times 0.75}{2\times 0.04} \qquad \sigma = 272.71\ KN/m^2$$

e) Longitudinal stresses

$$\sigma = \frac{pd}{4t} \qquad \sigma = 136.35\ KN/m^2$$

Step 2: Vertical load on pipeline due to fill material

As per IS 783-1983 load due to fill for positive embankment condition is given by,

$$W_e = C_e W D^2$$

The value of C_e can be obtained from Fig. 1 of IS 783-1983, Page No. 9

For $\frac{H}{D} = \frac{2.5}{0.83} = 3.01$ and $r_s \times P = 0.5\times 0.7 = 0.35$

$C_e = 5.98$ after interpolation

$$W_e = C_e W D^2 \qquad W_e = 5.98\times 18\times 0.83^2 \qquad W_e = 74.153 \text{KN/m}$$

Weight per unit length = 74.153 × 2.5

= 185.38 KN

Load on each node = $\frac{185.38}{30}$

= 6.1793 KN

Step 3: Vertical load on pipe due to superimposed loads (Traffic Load)

As per IRC equivalent single Wheel load is 41 KN i.e. P= 41 KN

S=0.3 m

$$\text{We} = \text{Cp} \times \frac{\text{P}\times\propto}{\text{L}}$$

α = 1 When load is Static

And from fig. 3 of IS 783-1983, C_p= 0.10

$$\text{We} = \text{Cp}\times\frac{\text{P}\times\propto}{\text{l}} \qquad \text{We} = 0.10\times\frac{41\times 1}{2.5} \qquad \text{We} = 1.672\ \text{KN/m}$$

Load per unit length = 1.672 × 2.5

= 4.18 KN

Load on each node = $\frac{4.18}{10}$

= 0.418 KN

Step 4: Horizontal side pressure load due to side support offered by compacted fill:

Let the angle of internal friction for soil is, Ø= 30º

$$K_a = \frac{1-Sin\text{Ø}}{1+Sin\text{Ø}}$$

At Top level of pipe,

$$\text{Side Pressure} = K_a\gamma H \qquad \text{Side Pressure} = \frac{1}{3}\times 18\times 2.5 \qquad \text{Side Pressure} = 15\ \text{KN}/m^2$$

At Bottom level of pipe, $\text{Side Pressure} = K_a\gamma(H+D)$

$$\text{Side Pressure} = \frac{1}{3}\times 18\times(2.5+0.83) \qquad \text{Side Pressure} = 19.78\ \text{KN}/m^2$$

Our calculated side pressure distribution is trapezoidal. But for calculation purpose, equivalent pressure distribution is assumed which is rectangular in nature i.e. UDL.

∴

$$\text{Equivalent Side Pressure} = \frac{15+19.78}{2}\ \text{KN}/m^2 \qquad \text{Equivalent Side Pressure} = 17.315\text{KN}/m^2$$

For a load calculation it is converted in UDL = 17.315 × 0.83× 2.5

= 35.875 KN

Side pressure on each node = $\frac{35.875}{30}$

= 1.19 KN

Step 5: Uplift Pressure Intensity:

$$\sigma_p = \gamma(H + D) \qquad \sigma_p = 17.31(2.5 + 0.83) \qquad \sigma_p = 59.94\ \text{KN}/m^2$$

Uplift pressure on full length = 59.94 × 0.83 × 2.5 = 124.37 KN

Uplift pressure on each node = $\frac{124.37}{30}$ = 4.145 KN

Step 6: Selection of bedding

As already mentioned, we assume the Type A bedding: Earth foundation

For Type A bedding, projection factor (P) is 0.75

$$P = \frac{h}{D}$$

Where, h- Distance from the top of the pipe down to undisturbed foundation level

$$h = P \times D \qquad h = 0.75 \times 0.83 \qquad h = 0.622m$$

Step 7: Calculation of Load factor (F_e)

For positive embankment condition and Type, A bedding for earth foundation

From section B- 10.4 of IS 783-1983 for projection ratio P = 0.75

F_e =2.3 (After interpolation) P = 0.7

Step 8: Selection of minimum test load

Total Load acting pipeline

= Vertical Dead load due to fill + Vertical load due to superimposed loads

= 74.153 + 1.672 = 75.825 KN

Here internal water load is not considered because we are analyzing the pipeline for critical load condition and the versed condition is when the internal loads are considered as zero.

$$\text{Minimum required strength or load} = \frac{75.825}{2.3} \qquad \text{Minimum required strength or load} = 32.96\ \text{KN/m}$$

Step: 9 Calculation of design horizontal seismic coefficient according to IS 1893- 2012 for zone IV

Total design base shear (V_B) = W × A_h

Horizontal seismic coefficient (A_h) = $\frac{Z\ I\ Sa}{2\ R\ g}$ = 0.09

Calculate Total Seismic Weight (W),

W= weight of fill + weight of pipe + weight of pipe inside the pipe

Weight of fill = 185.38 KN

Weight of pipe = perimeter × thickness × length × density of pipe material = πd × t × L × γ

= π × 0.83 × 0.040 × 2.5 × 25 = 6.518 KN

Weight of water inside pipe = volume of pipe × density of water = $\frac{\pi}{4} \times 0.75^2 \times 2.5 \times 10$ = 11.044 KN

Total seismic weight (W)= 185.38 + 6.518 + 11.044 = 202.972 KN

Base shear (V_B) = 202.972 × 0.09 = 18.267 KN

V_B for each node = $\frac{18.26}{30}$ = 0.589 KN

5. OBSERVATION AND REMARK

At the time of earthquake lateral forces are generated on the structural members.it becomes necessary to design super as well as sub structure subjected to horizontal force.

The underground pipeline is analyzed firstly without seismic forces (case I) and then considering seismic forces for soft soil for zone iv (case II). From the various table following remarks are drawn.

5.1 Node Displacement Summary

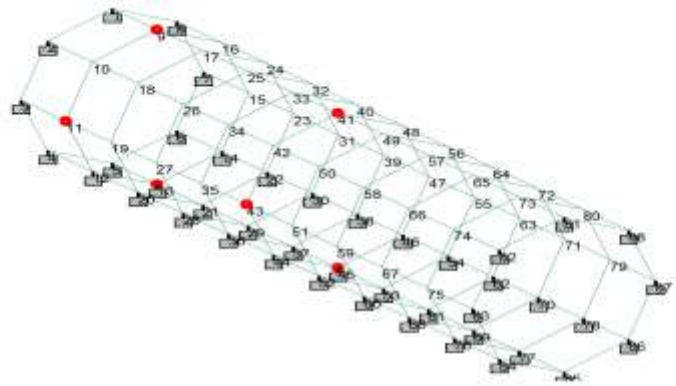

Fig.2 Considered Node for Node Displacement

Table No.1 Node Displacement Summary

	Node no.	Location	Resultant Displacement	Rotational		
				rX(rad)	rY(rad)	rZ(rad)
Case I	9	Exterior top node	15.533	0.065	0	0
Case II	9	Exterior top node	14.863	0.065	0	0
Case I	11	Exterior middle node	1.821	0	-0.005	0.012
Case II	11	Exterior middle node	1.345	0.006	-0.001	0.007
Case I	13	Exterior bottom node	0	0	0	0
Case II	13	Exterior bottom node	0	0	0	0
Case I	41	Central top node	41.201	0	0	0
Case II	41	Central top node	38.998	0	0	0
Case I	43	Central middle node	14.478	0	0	0.086
Case II	43	Central middle node	12.911	0	0	0.072
Case I	45	Central bottom node	0	0	0	0
Case II	45	Central bottom node	0	0	0	0

The nodal displacement values it is clear that the values for pipeline without seismic are less for the exterior and interior nodes considered at top, middle and bottom circumference of pipe. The values for case II are around 3 to 5 % less as that of case I. the rotational displacement for all the cases is negligible so as to consider as zero.

5.2 Support Reaction Summary

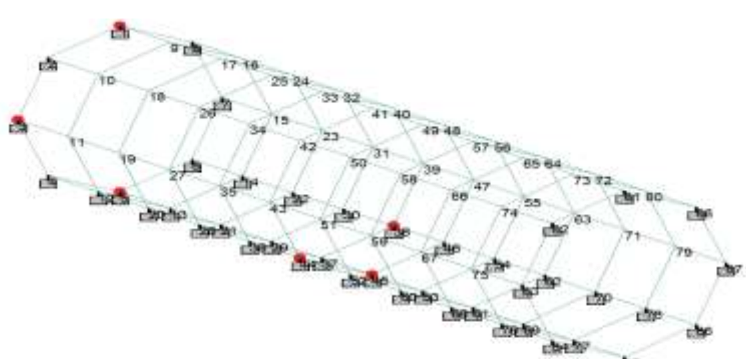

Fig.3 Considered Node for Support Reaction

Table No. 2 Support Reaction Summary

			Horizonal	Vertical	Horizontal	Moment		
	Node	Location	Fx(KN)	Fy(KN)	Fz(KN)	Mx	My	Mz
Case	1	exterior	0	21.898	-22.994	-0.197	0	0
Case	1	exterior	0	21.8761	-23.651	-0.202	0	0
Case	3	exterior	5.317	14.648	0.167	-0.109	0.258	-0.21
Case	3	exterior	3.286	20.057	-0.304	-0.15	0.19	-0.088
Case	5	exterior	0	-4.717	0	0	0	0
caseII	5	exterior	0	-4.717	0	0	0	0
Case	38	central	-2.318	2.745	2.172	-0.108	-0.431	0.436
Case	38	central	-0.875	3.047	7.421	-0.1	-0.392	0.399
Case	44	central	1.935	3.84	0	0	0	-0.444
Case	44	central	0.51	4.135	5.388	0	0.001	-0.406
Case	45	central	0	-3.217	0	0	0	0
Case	45	central	0	-3.217	0	0	0	0

It is observed from table 6.2 that the horizontal reaction at the top and the bottom node of pipe I zero. Whereas, the value of vertical forces Fy is same in both the cases as in node number 1, 5, 45. It is also observed that for node number 3 and 44 that is the middle node the forces in horizontal x and z direction are present.

5.3 Plate Center Stresses

Fig.4 Plate Center Stresses for Particular Plate

Table 3 Plate Center Stresses for Particular Plate

			Shear		Membrane			Bending		
case	Node no.	Location	Qx	Qy	Sx	Sx	Sx	Mx	My	Mz
			(N/mm2)	(N/mm2)	(N/mm2)	(N/mm2)	(N/mm2)	(KNm/m)	(KNm/m)	(KNm/m)
case I	1	Exterior top node	-0.096	-0.756	-0.031	1.262	0.811	-0.004	0.04	-3.495
Case II	1	Exterior top node	-0.098	-0.696	-0.046	1.181	0.975	-0.003	0.04	-3.124
Case I	3	Exterior middle node	0.133	0.026	-0.016	0.017	1.366	-0.004	-0.002	1.583
Case II	3	Exterior middle node	0.097	0.013	-0.013	0.012	1.892	-0.003	-0.001	1.069
Case I	4	Exterior bottom node	0	0	0	0	0	0	0	0
Case II	4	Exterior bottom node	0	0	0	0	0	0	0	0
Case I	41	Central top node	0.12	0.076	-0.357	-0.684	-0.027	-0.083	-0.022	0.532
Case II	41	Central top node	0.095	0.068	-0.45	-0.663	-0.243	-0.073	-0.02	0.474
Case I	43	Central middle node	-0.474	-0.015	-0.718	-0.186	-0.084	-0.05	-0.008	-0.81
Case II	43	Central middle node	-0.434	-0.015	-0.761	-0.19	-0.616	-0.042	-0.006	-0.737
Case I	44	Central bottom node	0	0	0	0	0	0	0	0
Case II	44	Central bottom node	0	0	0	0	0	0	0	0

Table no.6.3 represents the shear, membrane, and bending stresses within the plate. Plate center consideration the plate at the bottom is showing stress free behavior whereas the shear stresses are more for middle plate and that to for case I. The bending value is again higher for case I for all the plate as compares to pipeline subjected to seismic forces (case II).

5.4 plate corner stresses summary

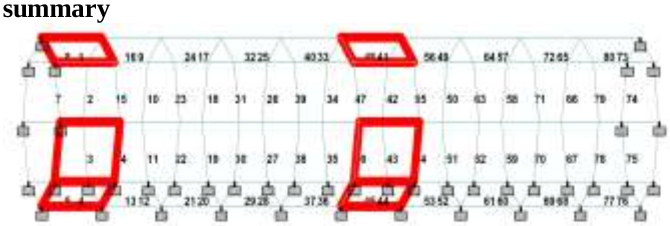

Fig. 5 Plate Corner Stresses at Particular Plate

Table No. 4Plate Corner Stresses for Particular Plate

	Plate	Location	Node	Shear		Membrane			Bending		
				Qx	Qy	Sx	Sx	Sx	Mx	My	Mz
case I	1	Exterior top plate	1	-0.097	-0.764	0.449	1.132	1.08	0.014	0.085	1.322
			2	-0.097	-0.748	-0.392	0.284	-0.192	0.001	0.004	-7.35
			10	-0.096	-0.748	-0.512	1.392	0.541	-0.011	0.075	-8.312
			9	-0.096	-0.764	0.33	2.24	1.813	-0.019	-0.006	0.36
case II	1	Exterior top plate	1	-0.099	-0.702	0.427	1.059	0.998	0.014	0.081	1.348
			2	-0.099	-0.688	-0.346	0.292	-0.156	0.002	0.009	-6.621
			10	-0.097	-0.688	-0.519	1.298	0.517	-0.01	0.071	-7.596
			9	-0.097	-0.702	0.254	2.064	1.671	-0.016	-0.001	0.372
case I	3	Exterior middle plate	3	0.133	0.028	-0.025	-0.003	1.419	-0.004	-0.019	0.774
			4	0.133	0.024	0.013	-0.027	1.346	0.002	0.005	1.064
			12	0.133	0.024	-0.007	-0.037	1.312	-0.008	-0.006	2.392
			11	0.133	0.028	-0.045	-0.06	1.385	-0.006	0.011	2.102
case II	3	Exterior middle plate	3	0.097	0.014	0.036	0.059	1.322	-0.003	-0.013	0.51
			4	0.097	0.011	-0.003	-0.003	1.363	0.001	0.003	0.651
			12	0.097	0.011	-0.059	-0.038	1.396	-0.005	-0.004	1.619
			11	0.097	0.014	-0.02	0.023	1.355	-0.004	0.007	1.479
case I	4	Exterior bottom plate	4	0	0	0	0	0	0	0	0
			5	0	0	0	0	0	0	0	0
			13	0	0	0	0	0	0	0	0
			12	0	0	0	0	0	0	0	0
case II	4	Exterior bottom plate	4	0	0	0	0	0	0	0	0
			5	0	0	0	0	0	0	0	0
			13	0	0	0	0	0	0	0	0
			12	0	0	0	0	0	0	0	0
case I	41	Central top plate	41	0.12	0.077	-0.417	-0.709	-0.081	-0.089	-0.031	-0.498
			42	0.12	0.074	-0.236	-0.43	0.184	-0.081	-0.012	0.37
			50	0.119	0.074	-0.298	-0.66	0.026	-0.081	-0.033	1.562
			52	0.119	0.077	-0.479	-0.939	-0.238	-0.071	-0.013	0.694
case II	41	Central top plate	41	0.095	0.069	-0.5	-0.691	-0.07	-0.078	-0.028	-0.387
			42	0.095	0.066	-0.341	-0.435	0.16	-0.072	-0.011	0.39
			50	0.094	0.066	-0.398	-0.635	0.021	-0.072	-0.029	1.333
			52	0.094	0.069	-0.558	-0.891	-0.209	-0.072	-0.012	0.556
case I	43	Central middle plate	43	-0.474	-0.016	-0.685	-0.146	-0.231	-0.044	-0.002	1.636
			44	-0.474	-0.014	-0.803	-0.061	-0.04	-0.059	-0.012	1.47
			52	-0.474	-0.014	-0.751	-0.227	0.062	-0.054	-0.007	-3.257
			51	-0.474	-0.016	-0.633	-0.311	-0.128	-0.043	-0.013	-3.091
case II	43	Central middle plate	43	-0.474	-0.016	-0.733	-0.156	-0.212	-0.036	0.002	1.511
			44	-0.474	-0.014	-0.841	-0.072	-0.037	-0.05	-0.011	1.347
			52	-0.474	-0.014	-0.789	-0.225	0.057	-0.046	-0.006	-2.98
			51	-0.474	-0.016	-0.681	-0.309	-0.118	-0.036	-0.012	-2.816
case I	44	Central bottom plate	44	0	0	0	0	0	0	0	0
			45	0	0	0	0	0	0	0	0
			53	0	0	0	0	0	0	0	0
			52	0	0	0	0	0	0	0	0
case II	44	Central bottom plate	44	0	0	0	0	0	0	0	0
			45	0	0	0	0	0	0	0	0
			53	0	0	0	0	0	0	0	0
			52	0	0	0	0	0	0	0	0

The table 6.4 shows the values of shear, membrane, and bending forces.at all the corner of plates under consideration. however, there is minor difference in plate corner stresses for case no. I and case no. II.

The shear and bending stresses are more for pipeline without lateral forces. While membrane forces are more for case no. II.

Again, the values of central plates are more as compared to the values of plate elements at the exterior face of pipeline. On the basis of this observation the conclusion is drawn in the next chapter.

6. CONCLUSION

One of the importance of the underground structure i.e. pipeline is studied over here for the Absence and presence of seismic forces. At the time of earthquake along with hazard to the building the lifesaving structure like hospital, roadway, tunnels and water pipeline etc. or also subjected to hazard. Thus, this dissertation the underground pipeline is checked for two cases i.e. case 1 without seismic forces and case II for with seismic forces the displacement, reaction, center and corner plate stresses are studied for exterior and interior elements along the circumferences. From the comparative observation it is observed that the displacement values are less when the lateral seismic forces are present. Further it is observed that shear stresses are more for middle plate. The value for bending and shear is less for pipeline with lateral seismic forces. The presence of lateral seismic forces for all possible direction looks like to increase the rigidity of structure thus the resultant values form displacement and corner stresses are less as compare to pipeline without seismic forces.

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