Comparative Analysis of Unburied and Buried Pipeline Structure in Seismic Zone Using CAESAR II

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ABSTRACT: The pipelines are the transfer medium wand economical linkage in the countries development and infrastructures. Pipelines are useful for transporting water for drinking or irrigation over long distances when it needs to transport over hills, or where canals or channels are poor choices due to considerations of evaporation, pollution, or environmental impact. Oil pipelines are made from steel or plastic tubes which are usually buried.

Seismic waves being a lead role in the destruction of pipeline networks. There different types of supports used to create stiffness. Distribution of bending moments, axial forces, displacements and deformations along the pipeline and supports are studied for a set of important parametric variations. A good representation of the pipeline displacements is shown using CAESAR II.

Key words: Pipeline, Types of supports, load cases seismic waves, unburied pipeline and buried pipeline.

1. INTROCDUCTION

Pipelines are usually a long pipes which are connected and used for long-distance transportation of a liquid or gas through a system of pipes. Liquids like water, crude oil, petrol, gases etc., which plays a major role in the present modern world and it is much better for transporting in pipelines rather than transporting in roadways and seaways. As the earthquake forces are hazardous in nature, we need to accurate engineering tools for analysing structures under the action of these forces. Thus, a careful modelling of such earthquake and wind loads needs to be done, so as to evaluate the behaviour of the structure with a clear perspective of the damage that is expected. To analyse the structure for various earthquake and wind intensities.

Seismic activity is a sudden movement of the earth's crust caused by a rapid release of earth crust energy. A seismic event is a relatively severe geological disaster, which not only destroys houses and buildings but also results in secondary disasters. Earthquake causes different shaking intensities at different locations and the damage induced in structures at these locations is also different. Thus, it is necessary to construct a structure which is earthquake resistant at a particular level of intensity of shaking and assimilate the effect of earthquake. Even though same magnitudes of earthquakes are occurring due to its varying intensity, it results into dissimilar damaging effects in different regions. Hence, it is necessary to study seismic behaviour of any structure for different seismic intensities. For determination of seismic responses.

There are two primary types of pipeline failure caused by an earthquake: first, the earthquake wave may cause the deformation of soil surrounding the buried pipeline, which would lead to excessive deformation of the pipeline until failure. This type of failure generally poses less of a threat to the pipeline under lower pressure, such as a water pipeline. Second, the failure is caused by the permanent deformation of the ground, which may occur during or after the earthquake, causing fault dislocations, landslides, etc.

In earthquake disaster areas, different pipeline stress analysis methods, based on different seismic resistance concepts, are used. For the relatively important pipelines, the limit-state design must be performed. The parameters for less probable earthquakes should be input, resulting in the design of a pipeline resistant to stronger earthquake action.

The CAESAR II software, developed by Intergraph, has in-built stress check standards, and a variety of load working conditions on actual situation of the project.

2. METHODS OF ANALYSIS

2.1 Piping Flexibility Analysis

Piping stress analysis is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, temperature changes, internal and external pressures. The purpose of stress analysis is to ensure safety of piping and piping components as well as the safety of connected equipment and supporting structure. Flexibility as well as stress analysis for this piping system is done through CAESAR II software. Operating loads are calculated using self-weight, operating pressure and temperature for the piping system, Sustained loads are by using self-weight and operating pressure and Expansion loads are due to temperature differences.

2.2 Finite Element Method

The objective of the finite elements method is to obtain a formulation that allows the analysis of complex and / or irregular systems through computer programs, automatically. To achieve this goal, the method considers the global system as being equivalent to a group of finite elements, in which each of these is a simple continuous structure.

3. STRESS ANALYSIS

In this Paper Static Analysis method is adopted for both Unburied and Buried Pipeline by using CAESAR II software.

Data:

Length of the pipeline	: 100m
Diameter of Pipe	: 610mm
Material	: A106 Grade B High-Strength Carbon Steel
Temperature	: 70°
Pressure	: 500
Seismic Zone	: IV

3.1 MODELLING

The entire model for Unburied and Buried Pipeline is generated by using CAESAR II software as shown below. For Unburied pipeline Anchor, Guide, Y or Rest supports are used for analysis.

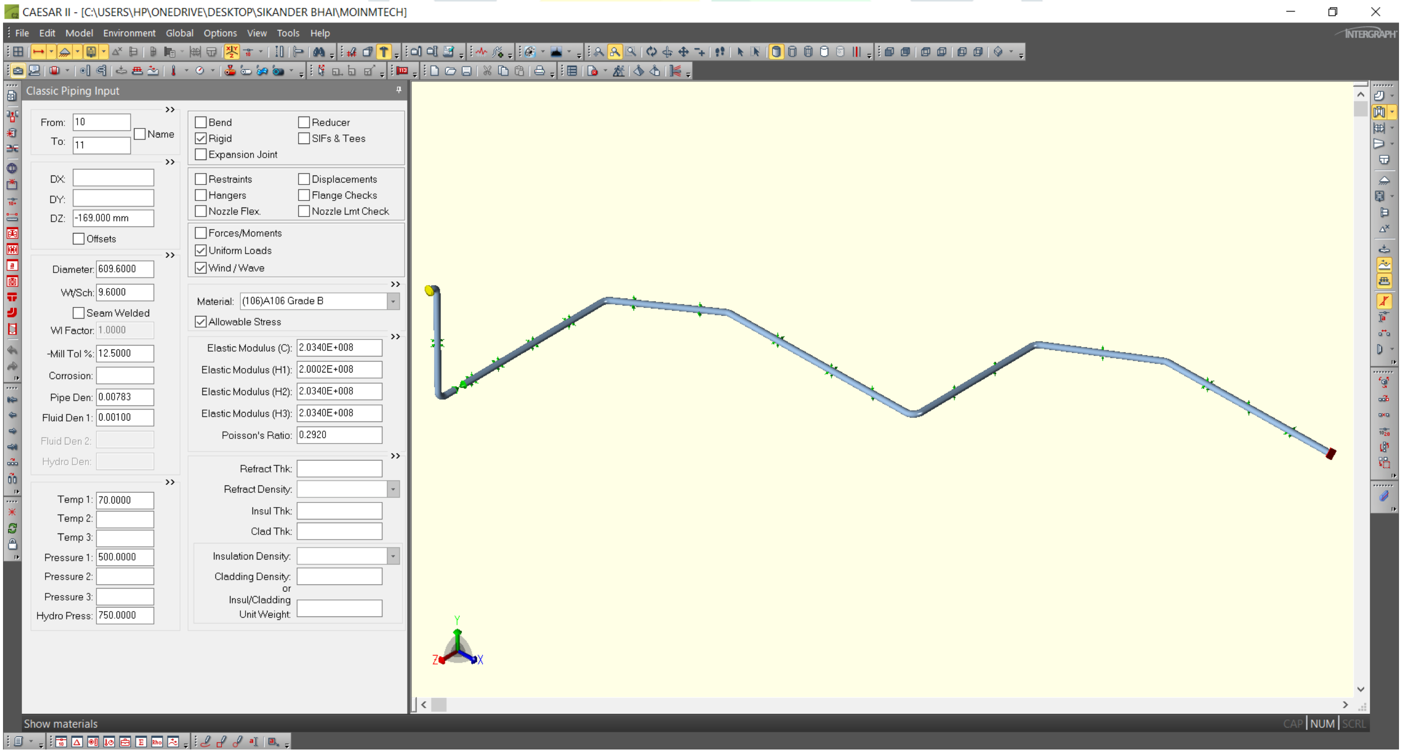

Fig 1: CAESAR II model

For Both Unburied and Buried pipeline same mechanical properties have been used as mentioned in the below table 1

PROPERTIES	TERMS	VALUES
Elastic Property	Density (kg/m3)	78330.43
	Young's Modulus MPa	2.034 × 105
	Poisson's Ratio	0.29
Plastic Property	Yeild Strength MPa	490
	Tensile Strength MPa	750

Table 1: Properties input for Unburied and Buried Pipeline model

For Buried pipeline soil parameters are taken as below

PARAMETERS	VALUES
Friction Coefficient	0.5
Soil Density (Kg/m3)	1800
Buried Depth To Top Of Pipe (mm)	2000
Friction Angle	30
Overburden Compaction Multiplier	8
Yield Displacement Factor	0.015
Thermal Expansion Coefficient	11.214
Temperature Change (Deg c^o)	70

Table 2: Soil Parameters for Buried Pipeline model

3.2 LOAD CASES

To meet these objectives several load cases are required during stress analysis.

- **Hydrostatic Case:** this pressure test that works by completely filling the component with water, removing the air contained within the unit, and pressurizing the system up to 1.5 times the design pressure limit the of the unit.

  HYD =WW+HP

- **Operating case:** When operation starts working fluid will flow through the piping at a temperature and pressure. Even occasional cases are also included. So operating load cases will be as mentioned below

  OPE = W+T1+P1
  W+T1+P1+EQ w.r.t $\pm$X, $\pm$Y, $\pm$ Z;
  W+T1+P1+Wind w.r.t $\pm$X, $\pm$ Z

- **Sustained Case:** Sustained loads will exist throughout the plant operation. The sum of weight and pressure are known as sustained loads. So our sustained load case will be as follows

  SUS = W+P1

- **Occasional Case:** Pipeline may be subjected to Occasional Wind and Seismic forces. So there are pure and impure occasional loads in pure occasional only wind and seismic forces are added. In impure Occasional loads along with wind and seismic forces Sustained case also added.

Pure OCC	EQ or U w.r.t ±X, ±Y, ± Z Wind w.r.t ±X, ± Z
Impure OCC	SUS+EQ w.r.t ±X, ±Y, ± Z SUS+Wind w.r.t ±X, ± Z

- **Expansion case:** The expansion case is a combination case that results from subtracting the sustained case from the operating case. The expansion case represents the change in the piping system due to the effect of temperature, with the presence of other loads. This is important because the restraint status of the operating and sustained cases can be different if there are nonlinear restraints (such as +Y, -Z, any restraint with a gap, etc.), or boundary conditions.

EXP=OPE-SUS

4. RESULTS AND DISCUSSION

4.1.1 Stress Analysis Report for Unburied pipeline

- Code Stress check Passed: L1 (HYD) =WW+HP

Highest Stresses: (KPa)

Ratio (%):	47.9	@Node	33		
Code Stress:	115529.2			Allowable Stress:	241316.5
Axial Stress:	11367.0	@Node	70		
Bending Stress:	104300.3	@Node	33		
Torsion Stress:	1421.7	@Node	70		
Hoop Stress:	23062.5	@Node	19		
Max Stress Intensity:	115791.4	@Node	33		

- No Code Stress check Processed: L2 (OPE) =W+T1+P1

Highest Stresses: (KPa)

Ratio (%):	0	@Node	33		
OPE Stress:	109413.2			Allowable Stress:	0
Axial Stress:	7564.5	@Node	11		
Bending Stress:	102028.5	@Node	33		
Torsion Stress:	1410.5	@Node	70		
Hoop Stress:	15375	@Node	19		
Max Stress Intensity:	109787.9	@Node	33		

- Code Stress check Passed: L13 (SUS) =W+P1

Highest Stresses: (KPa)

Ratio (%):	81.1	@Node	33		
Code Stress:	111773.1			Allowable Stress:	137895.1
Axial Stress:	7584.7	@Node	70		
Bending Stress:	104326.1	@Node	33		
Torsion Stress:	1422.1	@Node	70		
Hoop Stress:	15375.0	@Node	19		
Max Stress Intensity:	112035.4	@Node	33		

- Code Stress check Pass: L22 (OCC) =U3 or EQZ

Highest Stresses: (KPa)

Ratio (%):	86.8	@Node	50		
Code Stress:	159270.8			Allowable Stress:	183400.5
Axial Stress:	874.8	@Node	48		
Bending Stress:	212454.2	@Node	50		
Torsion Stress:	2831.7	@Node	30		
Hoop Stress:	0.0	@Node	11		
Max Stress Intensity:	212333.4	@Node	50		

- Code Stress check Passed: L34 (EXP) = OPE-SUS

Highest Stresses: (KPa)

Ratio (%):	7.8	@Node	69	
Code Stress:	25195.8	Allowable Stress:		323547.1
Axial Stress:	127.4	@Node	80	
Bending Stress:	25071.8	@Node	69	
Torsion Stress:	243.7	@Node	30	
Hoop Stress:	0.0	@Node	11	
Max Stress Intensity:	25195.8	@Node	69	

4.1.2 Stress Analysis Report for Buried pipeline

- Code Stress check Passed: L1 (HYD) =WW+HP

Highest Stresses: (KPa)

Ratio (%):	31.8	@Node	30	
Code Stress:	76656.3	Allowable Stress:		241316.5
Axial Stress:	12140.3	@Node	12	
Bending Stress:	86021.3	@Node	30	
Torsion Stress:	0.2	@Node	45	
Hoop Stress:	24650.0	@Node	19	
Max Stress Intensity:	98161.6	@Node	30	

- No Code Stress check Processed: L2 (OPE) =W+T1+P1

Highest Stresses: (KPa)

Ratio (%):	0.0	@Node	40	
OPE Stress:	112236.3	Allowable Stress:		0.0
Axial Stress:	13689.3	@Node	64	
Bending Stress:	104044.4	@Node	40	
Torsion Stress:	0.2	@Node	45	
Hoop Stress:	16433.3	@Node	19	
Max Stress Intensity:	128423.4	@Node	40	

- Code Stress check Passed: L9 (SUS) =W+P1

Highest Stresses: (KPa)

Ratio (%):	52.7	@Node	30	
Code Stress:	72627.1	Allowable Stress:		137895.1
Axial Stress:	8093.5	@Node	12	
Bending Stress:	86044.8	@Node	30	
Torsion Stress:	0.2	@Node	45	
Hoop Stress:	16433.3	@Node	19	
Max Stress Intensity:	94138.3	@Node	30	

- Code Stress check Pass: L14 (OCC) =U3 or EQZ

Highest Stresses: (KPa)

Ratio (%):	49.8	@Node	30	
Code Stress:	91308.8	Allowable Stress:		183400.5
Axial Stress:	1076.5	@Node	35	
Bending Stress:	120758.3	@Node	30	
Torsion Stress:	0.1	@Node	40	
Hoop Stress:	0.0	@Node	12	
Max Stress Intensity:	121498.4	@Node	30	

- Code Stress check Passed: L22 (EXP) = OPE-SUS

Highest Stresses: (KPa)

Ratio (%):	35.7	@Node	40	
Code Stress:	120329.8	Allowable Stress:		336641.7
Axial Stress:	21782.9	@Node	64	
Bending Stress:	104044.4	@Node	40	
Torsion Stress:	0.0	@Node	73	
Hoop Stress:	0.0	@Node	12	
Max Stress Intensity:	120329.8	@Node	40	

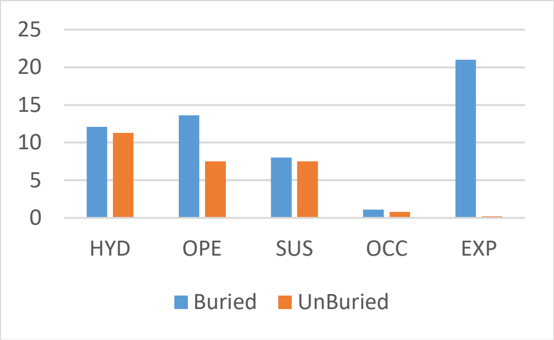

Chart 1: Axial Stress in MPa

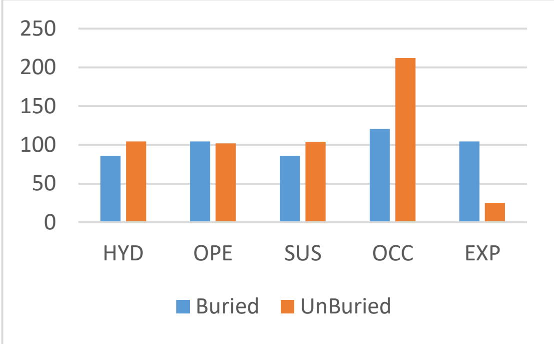

Chart 2: Bending Stress in MPa

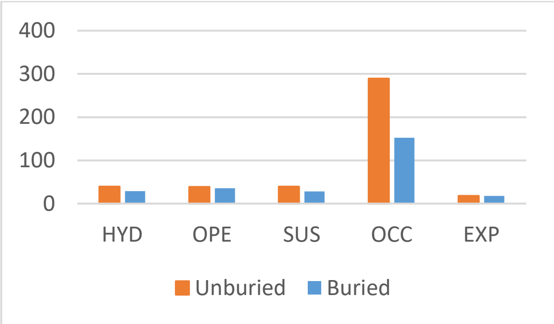

Chart 3: Maximum Displacement in mm

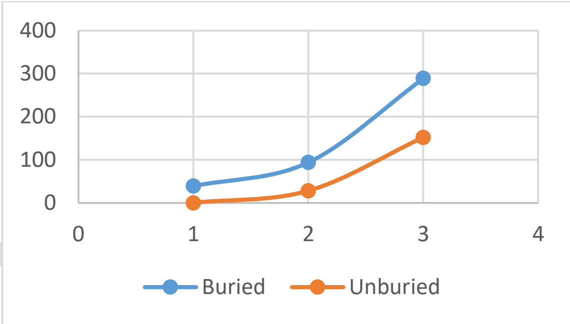

Chart4: Max and Min Displacements in OCC case

5. CONCLUSION

From the data revealed by the software analysis for the structure using various load combinations following conclusions are drawn:

- Based on the pressure and temperature, the stress value were changed at every node.
- Helps for understanding the minimum and maximum distance between two supports Unburied Pipeline.
- This Analysis helps for understanding the difference between both Unburied and Buried Pipeline system.
- Unburied Pipeline stresses are greater than Buried Pipeline stresses.
- Maximum Displacement is observed in Unburied Pipeline when compared to Buried Pipeline.

6. REFERENCES

- Pranav Nair, Dr. Shailendra Naik "Stress Analysis of Buried Pipelines" International Research Journal of Engineering and Technology Volume: 04, Issue: 06, July 2016.
- IITK-GSDMA Guidelines for SEISMIC DESIGN of BURIED PIPELINES, JULY 2001.
- IS 1893 Part 1 - 2016 Earthquake Resistant Design for Structures.
- ASME B31.1, Process Piping, ASME, New York-2006.
- Seshagiri rao boddu, rohini kumar "DESIGN AND ANALYSIS OF PIPE NETWORK SYSTEM BY USING EPANET" i-manager's Journal on Civil Engineering, Vol. 6 , No. 2 , March - May 2016
- S.Daniel Raj , M.V.Mohammed Haneef, S.Parthiba Raja, P.S.Naufal Rizwan S.Jansi Sheela "Seismic Response of Buried Pipe Lines and Preparation of Seismic Resistant Joint by Adopting Response Spectrum " International Journal of Oceans and Oceanography 2018
- Mariana Simao , Mora Rodriguez and Helena M. Ramos "Design Criteria for Suspended Pipelines Based on Structural Analysis" MDPI 2016.