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SUBMARINE PIPELINE DESIGN

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ABSTRACT

The principal objective of pipeline design is to select the pipeline dimension and route, and its method of fabrication, installation and protection so that it can transport the specified production requirement at an acceptable level of risk, whiles incurring minimum life cycle cost. To this end the pipeline engineering process, must consider the constraints imposed on the pipeline design by the nature of the environment, the methods of construction, operation and maintenance and the changing state of pipeline technology. This paper indented to described the route of pipeline project engineering, to understand the efects of pipeline to ocean engineering.

1. Route Reconnaissance and hazard Identification

The route of pipeline to avoid hazardous conditions starts with detalied surveys and geological studies of all the potential routes. These surveys define the seabed conditions including the locations of faults, slumps, slumps channels, diapirs and other geological features inclunding the soil conditions and the density and nature of local shipping. Side scan sonar, high resolution profiling, sub-botton profiling, soil coring and drop penetrometers are but some techiques used to provide the information. Geology-based geotechnical studies are an essential ingredient for analysing the route survey data to define relict conditions, initial hazards and the likely location and characteristics of future hazard. Knowledge of the underlying conditions that create the seafloor characteristics becomes a key factor in predicting the locations and characteristics becomes a key factor in predicting the locations and characteristics of these of similar hazard during the lifetime of the pipeline.

In deep water, pipelinescan be susceptible to a multitude of environment hazard with variable degree of severity. The designer may be required to demostrate that a pipeline has adequate serviceability under wave and current hydrodynamic loadings, dispplacements, induced by eartquakes and faulting, spanning accros botton irregularities, and sufficient strength and flexibility to accommodate the foces indced by slides. In effect, therefore, to devise a pipeline to withstand multiple hazard, the designer is confronted with conflicting requirements in his choice of methods for pipeline project and protection. On the other hand, to reduce forces caused by slides, it may be advantageous to place the line on the seabed, thus reducing potential soil loading and allowing the line to deform with lower induced stresses. An exposed pipeline is preferable in earthquake-prone areas, since the forces induced by an earthquake or fault movement are proportional to the amount of soil restrain around the pipeline. Furtermore, if the pipeline is unrestrained at the soil surface and croses faults at advantageous angles, then the induced forces will be greatly minimised. The positive and negative results of the various methods available of protection of the pipeline are noted relative to each of the primary environmental hazards. To reach an efective and efficient design for the pipeline, all conditions and constrains must be considered and their relative importance assessed so as to reach a balanced design that optimsed the realibility and cost of the line.

The principal classes of geotechnical hazard in deep water include:

-earth-shifts and fault movements that induce lateral and vertical forces on pipeline;

-bottom obstructions or irregularities, sand-waves and seafloor depressions caused by degassing, sliding or solution (in calcarous materials) and the effects of scour, which can result in pipeline spans.

Table 1. Constraints Involved in Pipeline Design

CONSTRAINT TYPE	DESCRIPTION
ENVIRONMENTAL	These require the definition of currents, fault movements, soil profiles and batymetry, which could affect the stability and integrity of the pipeline during its economic life.
CONSTRUCTIONAL	These include the equipment nneded for fabrication and nstallation, the specified of pipeline steels, welding and quality controls and pipeline bedding, bacfilling and armouring.
OPERATIONAL AND MAINTENANCE	The must cosidered the need for tie in points, flowrates, pressure and temperature profiles and the corrositivy of the fluids to be transported, methods of pipeline surveillance and monitoring, the need for maintenance and possibility repair, means of controlling fluid escape and emergency procedures.
DESIGN	These include the methods of analysis to be used, route guidelines, regulatory requirements and codes, allowable stressed and factor of safety. Economic consideration must include the cost of construction, operation, surveilance, maintenance failure and repair. Furthermore the potential effect of the pipeline on other systems must be fully explored for their economic, political, environmental and social effects, especially when these relate to a pipeline failure.

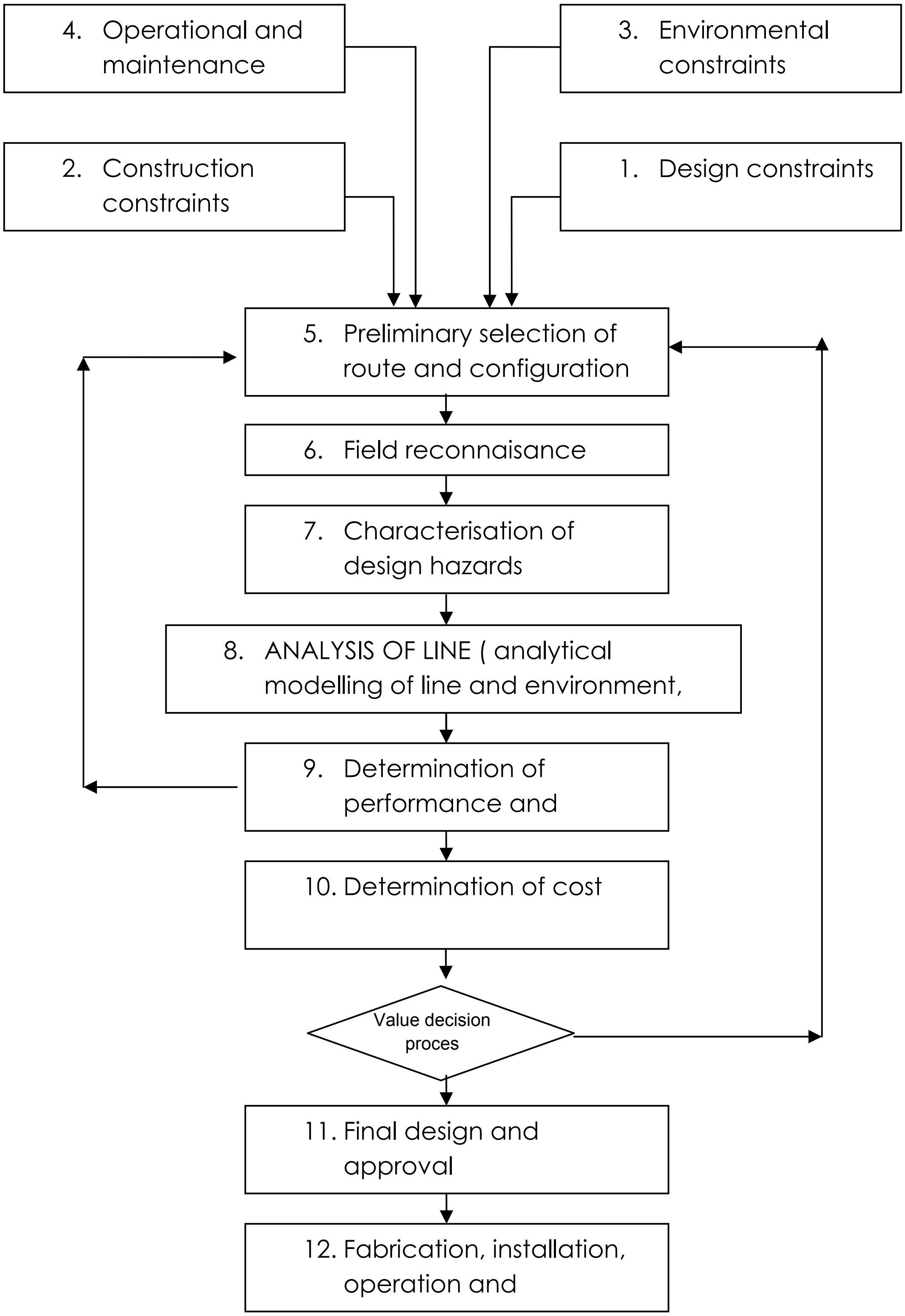
Table 2. Design consideration of Pipeline Design

ENVIRONMENTAL HAZARD	METHOD TO PROTECTIONS OF PIPELINE				
	BURY LINE	EXPOSE LINE	WEIGHT COATING	PIPE ANCHOR	STRONGER LINE
HYDRODYNAMIC LIFT, DRAG AND INERTIA	+	-	+	+	
VORTEX SHEDDING	+	-	+	+	+
SCOUR, PIPE SPANNING	+	-	-		+
SAND WAVES	+	-		+	+
MUDSLIDES, MUDFLOWS AND TURBITY CURRENTS	-,*	+	-	-	+
FLOATATION	+,**	-	-	+	+
LIQUEFACTION	***	***	***	***	***
MUDLUMPS, IAPIRS	-	+	-	-	+
FAULTING, EARHQUAKES	-	+	-	-	+

NOTES:
(+) positive results produced from method of protection;
(-) negative results produced from method of protection;
(*) pipeline in mudslide area;
(**) pipeline dowsteram in mudslide area;
(***) design pipeline so that its unit weight be as close as possible to unit weight of fluidised soil.

A wide variety of geologic and oceanographic processes combine to influence these hazards in deep water. These include:steep slopes, bankets of soli soft, outcrops of very old sediments (associated with the formation of ocean basins involving calcareous or salt accumulated), the interaction of deep ocean and shallow water continental shelf processes (such as the breaking of internal waves and turbity flows initiated by storm affecting shallow water sediments). They either induce loadings on pipelines (slides) or remove support from pipeline.

Table 3. Pipeline Design Methodology



2. Characterisation Problems with Deep Seabeds

Currently, five basic techiques are used to characterise depseea soil conditions. These comprise side-scan sonar surveys, high resolution geophysics, electric, nuclear and acoustic logging, sediment sampling ans physics, electric, nuclear and acoustic logging, sediment sampling and testing, and in situ test using a variety of penetrometer and pressure meter device. All these mhetods employ proven techniques and equipment, which are used regulary in shallow water, and with special adaptations they can also be used in deepwater service. The special difficulties with their application in deep water result primarily from equipment design problems associated with high pressure and the need for pressure relief upon retrieval. It should be noted that equipment problems have often been the main cause of misleading data and information on deepwater geotechnical surveys. Until these equipment problems are solved, the large uncertainies of identifying the seafloor conditions, hazard characteristics and soil characteristics will prevail, and the geotechnical engineering of deepwater pipelines will remain more of an art than a science.

3. The Study of Soil-Pipeline Interaction

Four major categories of geotechnical problems are reevant to pipeline design, namely:

- The identification of seafloor movement zones;
- The determination of soil loadings or deformation associated with these zones;
- The determination of soil restrain active at the time of pipeline movement;
- Consideration of construction effects such as botton tows, trenching and burial.

The following considerations are of primary importance in the mechanics of soil-pipeline interaction:

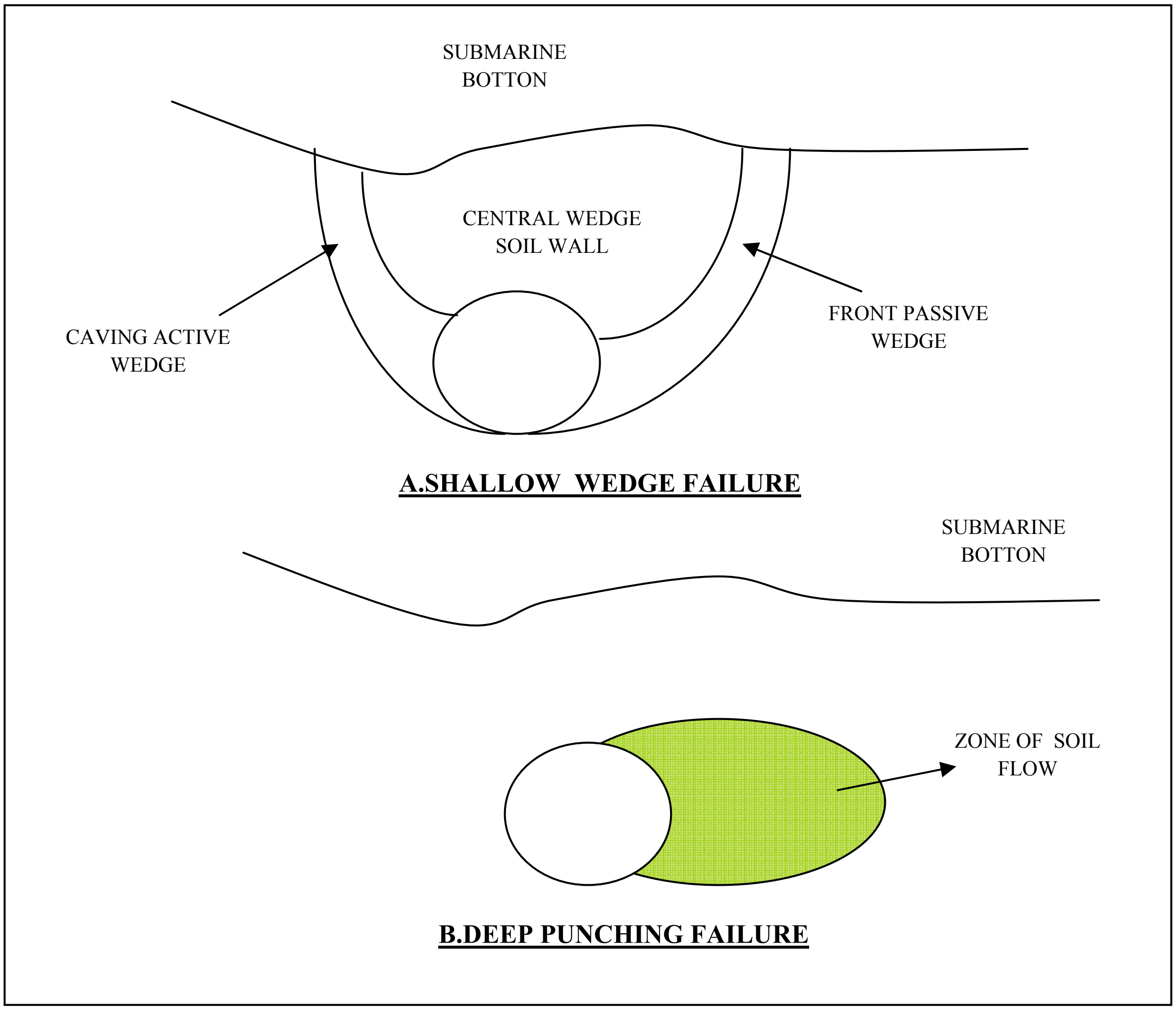
- Soil behave as nonlinear, inelastic, non-homogenous materials;
- Pipelines behave as nonlinear, inelastic elements;
- Most of the analytical models currently used to characterise soil-pipeline interaction fall far short of simulating reality, due principally to their deficiences in dealing with the important elements of nonlinear behaviour;
- Engineering estimates involved with the characterisation of soils and pipelines that were originally intended to provide conservative designs, can, under certain circumstances, provide unconservative results for some pipeline design problems, especially those associated with slides, faults and earth movements.

Much experimental and analytical work has been done to characterise soil response for a wide variety of pipeline-soil interaction problems.

4. Pipeline Behaviour in Slides

One of the most common deepwater geotechnical hazards in that of slides wich can be initiated by a wide variety of phenomena, including earth quakes, waves, currents, and simply by exvessive deposition of week soils on steep slopes. The soil strenght and water content profile chosen for the purpose wich shows that, close to the mudline, the soil is weak with a shear strength approximately 40 to 80 pounds per square foot (1,9 to 3,9 kPA) in the top 3 to 4 feet. However the strenght increases significantly whit depth. It also shows that the water content of the near surface soils usually exceeds 100 per cent, in wich case they behave morte like fluids that plastic solids.

Figure 1.Soil-Pipeline Interaction

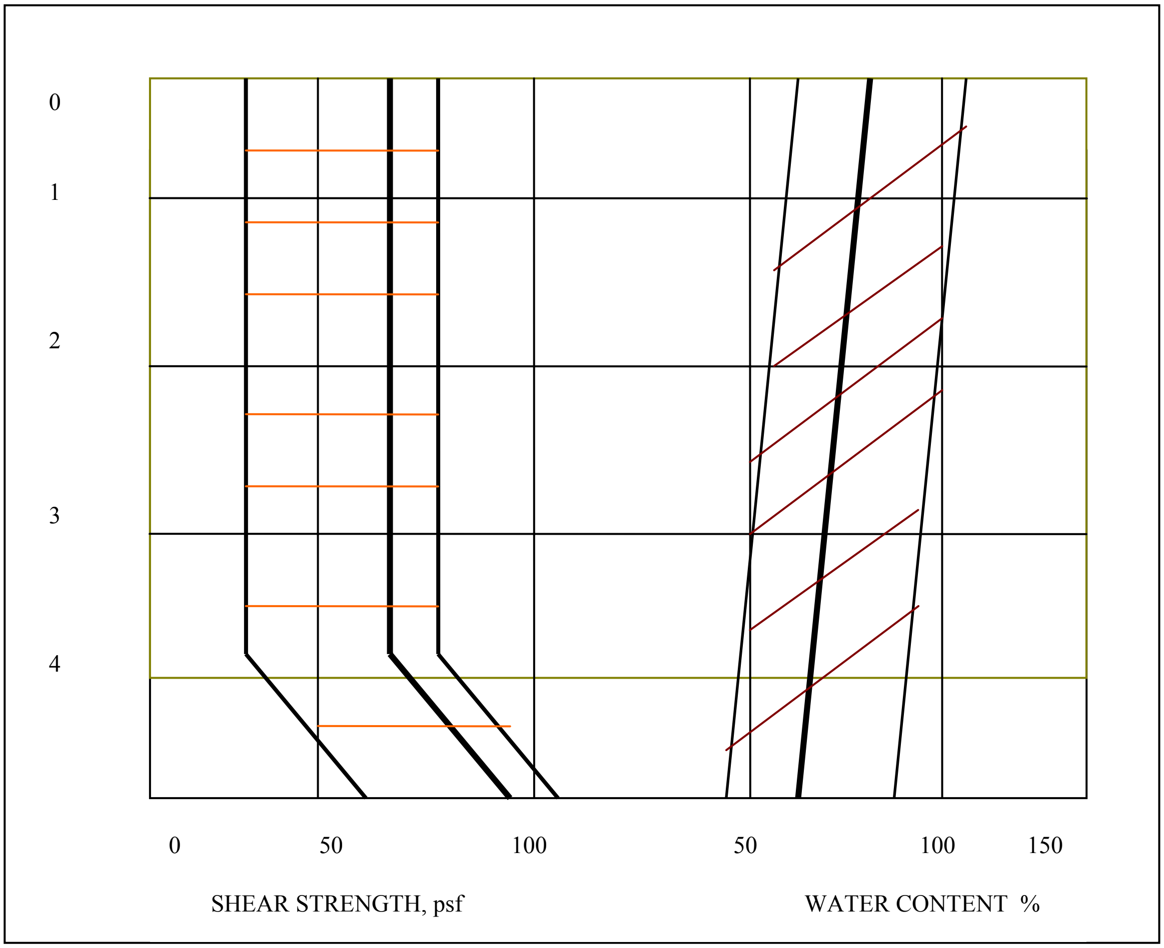


In figure 2 shows the stressed wich are induced in a 12 inch pipeline diameter when it is subjected to a slide having a width of 500 feet moving perpendicular to the pipeline axis. The stress levels referenced are those of an equivalent elastic pipeline. The true nonlinear yielding response of the pipeline was include in the analytical model. These results show that if the pipeline can be keep or weighted to remain close to the mudline, then if would be able to withstand the range of potential slide forces. However, if the line were buried beyond a deep of 1 to 2 feet, then extensive yelding would result. Note that the concrete cover basically has the effect of increasing the diameter of the pipeline and increasing the forces by the slide, with no strength benefit. These results are sumarised in Figure 2 and wich plots the maximum tensile stress in the pipe *F/S* (measured in psi) is:

$$F / S = \frac{S \times W}{D \times t} \qquad (1)$$

D is pipe diameter in inch, *t* is wall tecknesses in mm, *F/S* is soil forces at the depth of self burial (S) in meter and slide widths (*W*) in meter.

Figure 2.Soil Shear Strenght and Water Content in Slide Area



5. Conclusion

For the majority of pipelines wich will be founded in deep water, few unsolvable geotechnical exist. Most of their sites are expected to be relatively quiescent, with stable and reasonably undestood soils. However, deepwater pipelines wich intend to cross active marine slopes can expected a wide variety of impostant geotechnical problems incliding slide forces, displacements and spanning forces displacements. The principal sources of these uncertainties lie in our lack of knowledge of geotechnical oceanographic soil loads and restrain on pipeline.

6. Bibliography

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