# EMAS AMC (Singapore)

## Engineering 'Lunch & Learn' Series

## "Use of Spoilers for Pipeline Self-burial"

18 March 2013

***WIN – EXECUTE – SAFE DELIVERY***

# Introduction

- Pipeline burial is normally carried out by pre-trenching (dredging) or post-trenching (e.g. jetting).

- A non-conventional method of pipeline burial is by implementation of spoilers on the pipeline. Where conventional method is not practical or cost effective, e.g. where pipeline is subject to scouring, a self-burial device known as “Spoilers” could be used. This could effective ensure that the pipeline will self bury after becoming exposed due to scouring.

- If a previous buried pipeline is exposed due to scouring, it will be placed at risk due to pipe instability (insufficient weight), unacceptable free-spans, and potential damage by third parties due to lack of cover.

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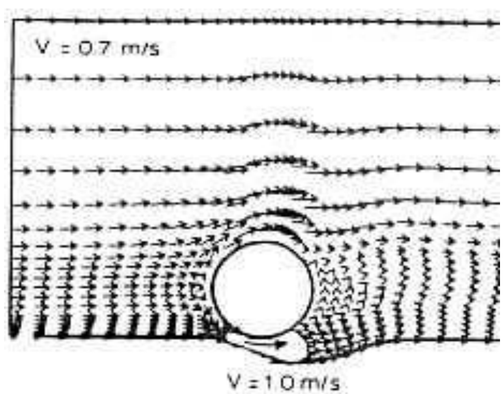
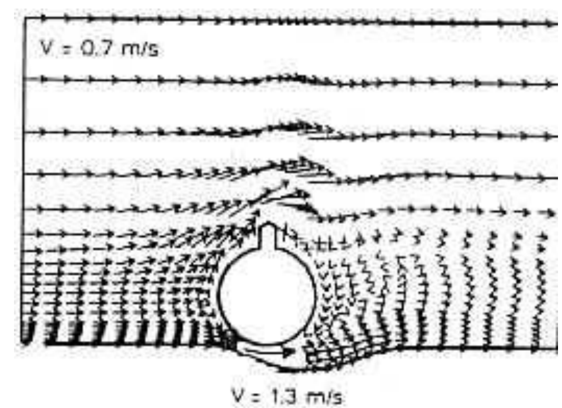
# Spoiler Mechanics

The effect of spoiler is based on scouring and fluid mechanical process. The spoiler, which is fitted on the top of pipeline, changes flow pattern around the pipeline compared with a plain pipeline, as shown in Figure 1.




**Plain Pipeline**




**Pipeline with Spoiler**

**Figure 1 – Flow pattern of plain pipeline and spoiler-fitted pipeline**

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# Spoiler Mechanics (Cont'd)

- The spoiler causes an increased flow velocity underneath the pipeline. This results in tunnel erosion taking place at lower ambient velocities than with a plain pipe and more aggressively not only in the vertical direction but also along the pipeline length.

- The spoiler brings about significant changes in the flow pattern and results in:
  - Smaller upward lift forces when the pipeline is in contact with the seabed;
  - Increased downward (negative) lift forces when the pipeline lifts off from the seabed;
  - Increased hydrodynamic drag and inertia coefficients;
  - Suppressed vortex shedding;
  - Increased stability of the hydrodynamic process - less scatter in drag and lift coefficients.

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# Schematic of self-burial of a spoiler-fitted pipeline

The following schematic illustrates the phases and manner in which a spoiler-fitted pipeline achieves self-burial

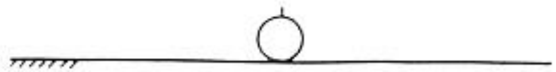
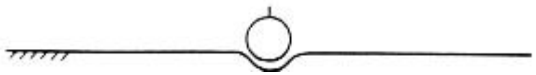
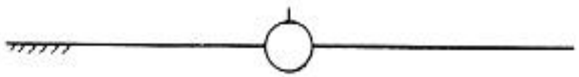
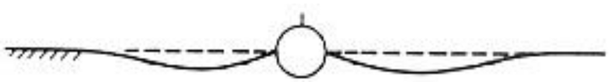
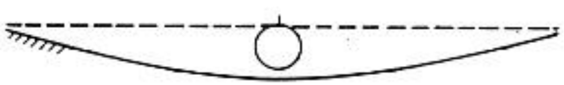
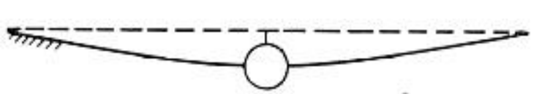
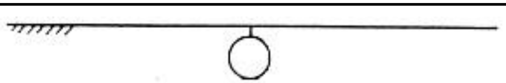
| | |
|---|---|
|  | touch down |
|  | first tunnel erosion, pipe is sagging |
|  | Partial Burial |
|  | start leeside erosion |
|  | pipe on ridge |
|  | second tunnel erosion, pipe is sagging |
|  | second partial burial |
|  | natural backfilling to original seabed |

Figure 2: Self-burial illustration

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# Spoiler Mechanics

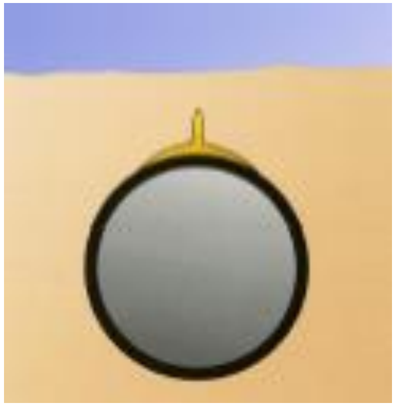
| | | |
|---|---|---|
|  |  |  |
| First Stage -Touch Down | Second Stage – Tunneling | Final Stage - Burial |

Figure 3:  Self-burial Stages

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# Spoiler Mechanics

Optimal performance of spoiler for pipeline self-burial is best achieved under certain environmental conditions as shown in Table 1 below.

Based on the results of tests conducted by SPS at Delft Hydraulics Institute in Holland, sufficient tidal current velocity as well as a highly erodible seabed condition should be available to invoke the tunneling erosion effect, which is the mechanism of the self-burial process of pipeline.

**Table 1 – Environmental Conditions for Optimal Spoiler Performance**

| | **Complete Burial Expected** | **Partial Burial Expected** |
|---|---|---|
| Seabed Material (Top Layer) | Sand + Maximum of 10 % Silt | Sand + Maximum of 20 % Silt |
| Current | Tidal current more than 0.8 m/s | Tidal current more than 0.4 m/s |

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# On-bottom Lateral Stability of Spoiler-fitted Pipeline

A simple static approach, based on DNV 1981 (Ref.[4]), is adopted for the analysis of the lateral stability of the pipelines.

The latest DNV code for stability analysis could not be easily modified to account for effect of pipe self-burial and it's resultant passive resistance. Hence, DNV 1981, which could be easily modified to take into account the effect of passive resistance and change in hydrodynamic coefficients, remains adopted for the analysis.

A minimum factor of safety of 1.1 set by DNV 1981 (Ref.[4]) has been used for the analysis. The forces action on spoiler fitted pipelines embedded in soil is schematically presented in Figure 4.

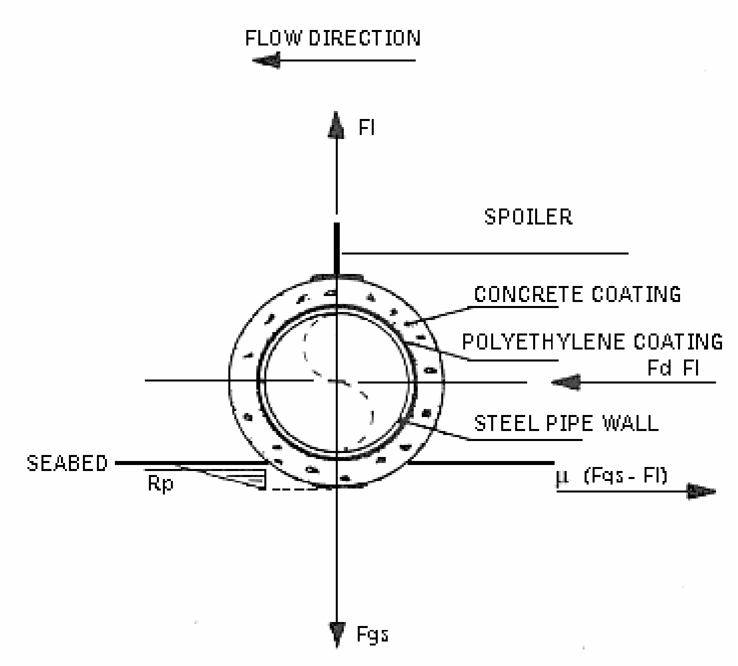


**Figure 4 – Forces acting on the spoiler pipe embedded into soil**

# On-bottom Lateral Stability of Spoiler-fitted Pipeline (Cont'd)

The stability criteria for the pipeline embedded into soil can be expressed as:

$$\frac{\{\mu(F_{gs} - F_L) + R_P\}}{F_D + F_I} \geq 1.1$$

Where :

| | | |
|---|---|---|
| Fgs | = | Submerged weight of the pipeline (N/m) |
| FL | = | Hydrodynamic lift force per unit length (N/m) |
| FD | = | Hydrodynamic drag force per unit length (N/m) |
| FI | = | Hydrodynamic lift forces per unit length (N/m) |
| μ | = | Coefficient of lateral friction between pipe and seabed |
| RP | = | Passive soil resistance (N/m) |

# On-bottom Lateral Stability of Spoiler-fitted Pipeline (Cont'd)

- Based on the Morrison equations, the drag force, lift force and inertia force per unit length of pipeline length can be calculated as follow:

$$F_D = \frac{1}{2}\gamma_w C_D D_t U_d |U_d| \qquad F_I = \frac{\pi}{4}\gamma_w C_I a Sin\phi \qquad F_L = \frac{1}{2}\gamma_w C_L D_t U_d |U_d|$$

| | | |
|---|---|---|
| $\gamma w$ | = | Mass density of seawater (kg/m3) |
| $C_D$ | = | Drag coefficient |
| $C_L$ | = | Lift coefficient |
| $C_I$ | = | Inertia coefficient |
| $D_t$ | = | Total diameter of pipeline including coating (m) |
| a | = | Horizontal water particle acceleration normal to the pipe axis (m/s2) |
| $U_d$ | = | Horizontal water particle velocity normal to the pipe axis |
| | = | Uc + Uw Cos$\phi$ (m/s) |
| $U_c$ | = | Horizontal steady current velocity normal to pipe axis (m/s) |
| $U_c$ | = | Wave induced horizontal water particle velocity normal to pipe axis (m/s) |
| $\phi$ | = | Phase angle |

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# On-bottom Lateral Stability of Spoiler-fitted Pipeline (Cont'd)

The lateral friction factor for a pipeline resting on the seabed for sandy soil condition is 0.7, corresponding to a soil internal friction angle of 35°. Embedment of pipe increases the passive soil resistance. The soil resistance due to embedment can be calculated as follows:

$$R_P = \frac{1}{2} \lambda_P \gamma_s z^2$$

where: $\lambda_P$ = Passive Earth Pressure Coefficient (-)

$\gamma_s$ = Soil Submerged Density (N/m3)

z = Depth of Embedment (m)

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# Hydrodynamic Coefficients

- The Hydrodynamic coefficients for spoiler fitted pipes are taken from SPS report (Ref.[1]).  The values of CD, CM and CL for various pipe embedment extracted from above mentioned report is presented in Figures 4, 5 and 6, respectively.

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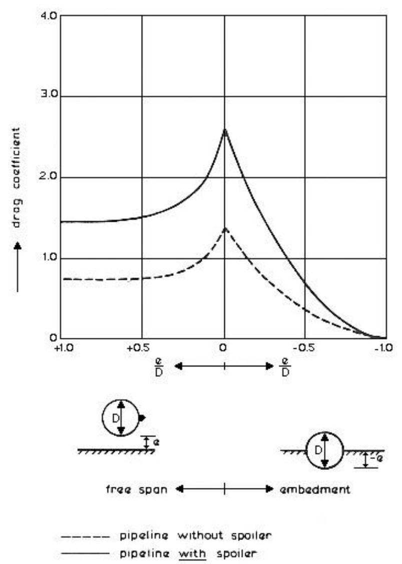
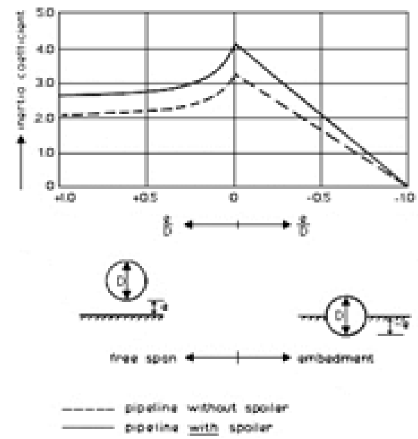
# Hydrodynamic Coefficients (Con’td)




**------** pipeline without spoiler

_____ pipeline <u>with</u> spoiler

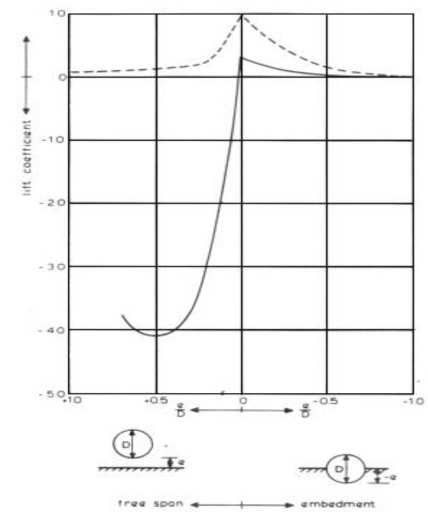
**Figure 5 – Hydrodynamic Drag Coefficient ($C_D$)**




**------** pipeline without spoiler

_____ pipeline <u>with</u> spoiler

**Figure 6 – Hydrodynamic Inertia Coefficient ($C_M$)**




------ pipeline without spoiler

_____ pipeline <u>with</u> spoiler

**Figure 7 – Hydrodynamic Lift Coefficient ($C_L$)**

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# Hydrodynamic Coefficients (Con’td)

The values of $C_D$, $C_M$ and $C_L$ for various pipe embedment extracted from the above figures are summarized in Table 2.

**Table 2 – Hydrodynamic Coefficients Versus Pipe Embedment**

| Hydrodynamic Coefficient | Pipe Embedment (e/D) | | | | | | Hydrodynamic Coefficients based on DNV 1981 |
|---|---|---|---|---|---|---|---|
| | 0% e/D | 10% e/D | 20% e/D | 30% e/D | 40% e/D | 50% e/D | 0% e/D |
| Drag ($C_D$) | 2.60 | 2.00 | 1.60 | 1.30 | 1.00 | 0.70 | 1.30 |
| Inertia ($C_I$) | 4.10 | 3.90 | 3.50 | 3.00 | 2.55 | 2.10 | 3.29 |
| Lift ($C_L$) | 0.31 | 0.20 | 0.16 | 0.10 | 0.07 | 0.05 | 1.0 |

# Analysis Approach

**Lateral stability is carried out for the following cases in line with recommendations given by SPS:**

| Case (a): During initial period (Installation) | |
|---|---|
| Pipe condition | Empty |
| Environmental condition | 3-month construction weather window (80 % of 1-year return wave) |
| Pipe embedment | 30 % of outer diameter |

| Case (b): After installation but prior to operation | |
|---|---|
| Pipe condition | Empty |
| Environmental condition | 1-year return wave and current |
| Pipe embedment | 50 % of outer diameter |

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# Analysis Approach (Cont'd)

| Case (c): Initial period of operation | |
|---|---|
| Pipe condition | Product-filled |
| Environmental condition | 10-year return wave and current |
| Pipe embedment | 50 % of outer diameter |

| Case (d): Operating condition | |
|---|---|
| Pipe condition | Product-filled |
| Environmental condition | 100-year return wave and current |
| Pipe embedment | Fully buried |

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# Installation of Spoiler-fitted Pipeline

- Spoilers are typically manufactured in either 3.8m or 5.6m lengths.

- Each section of spoiler consists of two parts, i.e. fin and template. The fin is inserted into slot of the template. The details of the spoiler are shown in Figure 8.

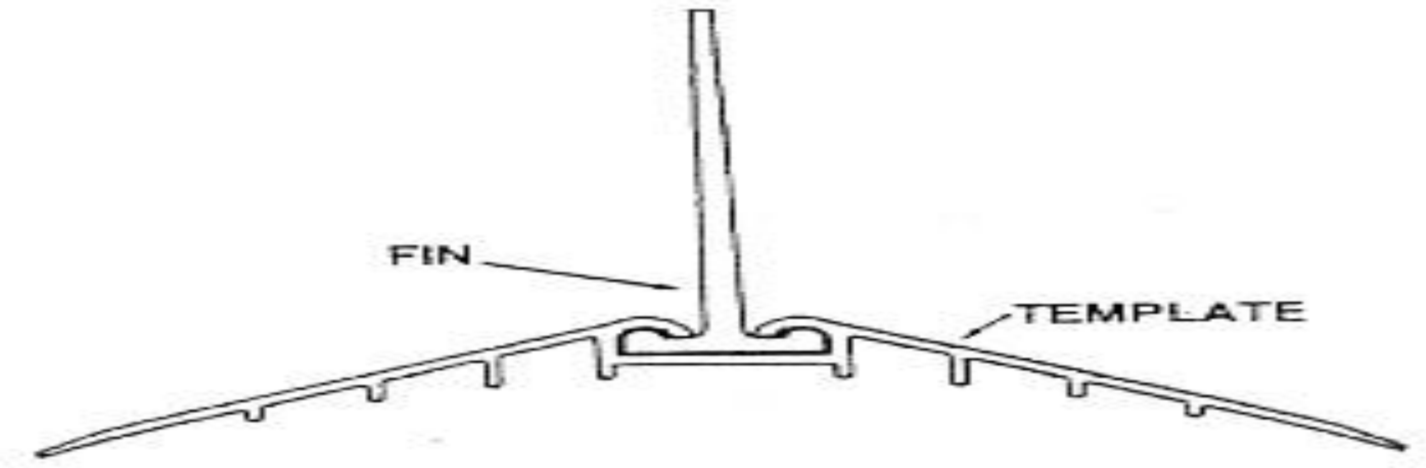


**Figure 8 – Spoiler Details**

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# Installation of Spoiler-fitted Pipeline (cont'd)

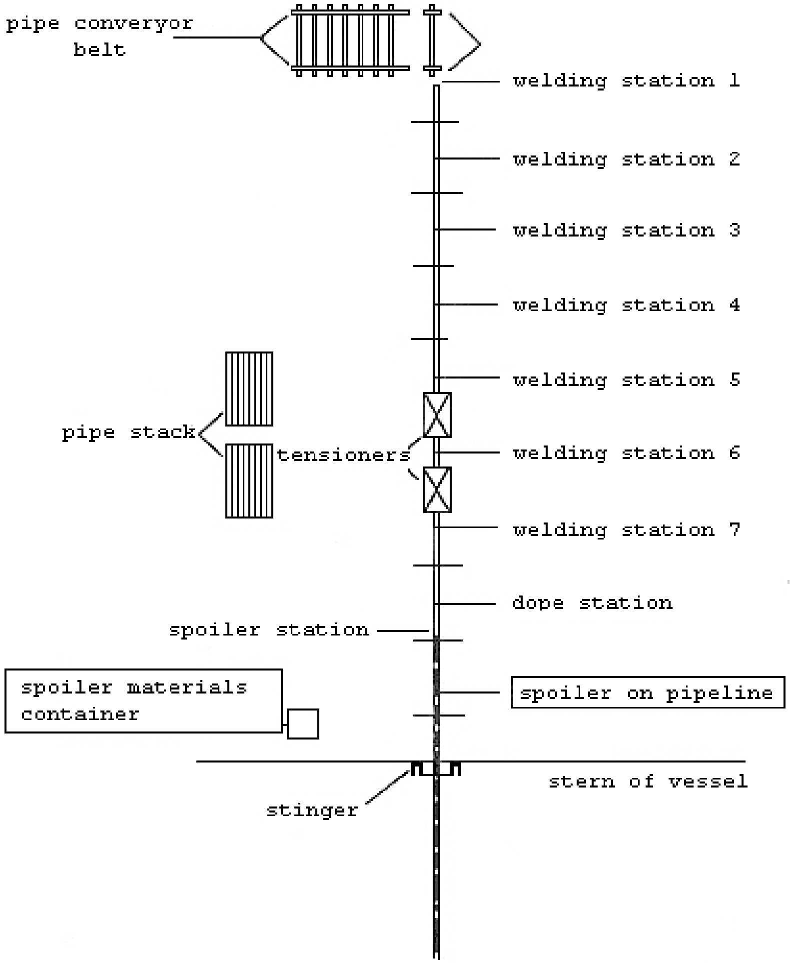


**Figure 10 – Location of Spoiler Station on Typical Laybarge**

- The spoilers are positioned at top dead center of the pipe (12 0'clock position).
- At this position, the spoiler is most efficient in its scouring effect.
- Each section of the spoilers is attached to pipeline with 4 x alloy 625 metallic straps and 2 x sacrificial carbon steel straps that pass through the holes in the fin and over the template.
- A spacing of 100 mm is maintained between the spoiler sections.

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# Photo from site (laybarge)

Spoilers are strapped on pipeline at stern of laybarge, just before entrance to stinger

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# Photo from site (taken from stern of laybarge)

Pipeline with spoiler traveling down the stinger in “strong” current

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# Photo from site (shore approach to landfall)

View of pipeline at shore approach during low tide.  Note that minor rotation had occurred during pulling operation, partially due to flooding and receding tides.
Note scour on both sides of pipeline due to spoiler effects.

# Photo from site (stern of laybarge)

Spoilers strapped on pipeline at stern of laybarge, just before entrance to stinger

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# Photo from site (taken from stern of laybarge)

Pipeline with spoiler traveling down the stinger in “strong” current

# Photo from site (approach to landfall)

View of pipeline at shore approach during low tide. Note that minor rotation had occurred during pulling operation, partially due to flooding and receding tides.

Note scour on both sides of pipeline due to spoiler effects.

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# Photo from site (taken from stern of laybarge)

Pipelaying in ‘mild’ current

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# Photo from site (pipeline on stinger)

Pipeline subjected to high bending forces during “peak”current

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# Photo from site (pipeline on stinger)

Pipe coating & spoiler damaged during pipelaying in very strong current

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# Photo from site (stern of laybarge)

Damaged pipeline “recovered” back to laybarge for cut-out and replacement

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# Risks and Challenges

- The main risk associated with utilizing the spoiler is the effect of additional hydrodynamic forces caused by the presence of the spoilers if self-burial did not occur immediately upon touchdown.

- Ideally, a contingency plan should be in place of the “worst case” scenario, i.e. spoiler fails to initiate self-burial fast enough. A feasible contingency plan is to have a jetting spread on standby. The jetting equipment should be modified such that the spoiler fin will not be damaged during jetting.

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# Field Verification of Spoiler Performances

- For Hangzhou Bay project, subsea survey was carried out regularly during pipelaying to determine the burial condition of the pipeline.
- Generally, it was found that the pipeline underwent burial almost upon touchdown and the tunneling effect continued until almost all the pipeline was below the natural seabed.
- In areas where there were greater concentrations of fine particles, the burial rate proceeded at a slower rate and portions of the pipeline continued the tunneling at a slower rate until the top of pipeline was below the natural seabed.
- As-built survey of the pipelines showed that prior to hydrotesting, the entire pipeline route achieved at least 50% burial and considerable portions achieved complete burial to over one meter of cover.

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# Conclusions

- The spoiler is particularly suited for areas which experience strong bi-directional currents and have erodable seabed.

- The spoiler is also suitable in areas where dynamic movement of seabed profile is experienced, e.g. Hangzhou Bay, When the pipeline is exposed to the environment due to scouring, the spoiler is expected to re-initiate burial.

- Based on the successful use of spoilers in the Hangzhou Bay Pipeline Crossing project, as well as other applications in the North Sea, it is envisaged that the spoiler would find many more uses for similar projects under similar conditions worldwide.

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