ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT

PRESENTER:
Angelina Parlato
Onshore Pipeline Engineering Department - Saipem, Italy

AUTHORS:
Agostino Napolitano, Diego D’Alberto, Salvatore Morgante
Onshore Pipeline Engineering Department - Saipem, Italy
Angelo Rosato
++39, Italy

Geneva, October 17
ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT

Lessons from the Pipefall Incident from Support resulting in two Fatalities:

https://www.youtube.com/watch?v=0SQqSmHGMyo&feature=youtu.be
ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT

Lessons from the Pipefall Incident from Support resulting in two Fatalities:

https://www.youtube.com/watch?v=0SQqSmHGMyo&feature=youtu.be
ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT
CONTENTS

- Introduction & input data
- Stability analysis of the *crutch skids*
- Global analysis of *pipeline string* and evaluation of the forces acting on the skids
- Analysis of *skid stability improvement*
- Conclusion, Recommendations, Developments
KEY MAP

- **Introduction & input data**
- **Stability analysis of the *crutch skids***
- **Global analysis of *pipeline string* and evaluation of the forces acting on the skids**
- **Analysis of *skid stability improvement***

**Conclusion, Recommendations, Developments**
Geneva, October 17

ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT

- Steel pipe 48”, 24.1 mm thick, coated in HDPE
- Bar length: 12 m
- Wooden stocks: 140 mm x 140 mm x 1100 mm, class C14 - EN 338
- Slide skids A: vertical support only (V)
- Crutch skids B: vertical and lateral support (V and H)
- One crutch skid B (type 1, 2 or 3) for every 4 slide skids A
- Spacing between two crutch skids type B: 60 m

**INTRODUCTION & INPUT DATA**

**SKIDS SUPPORTING: GEOMETRY AND BEHAVIOR**

- **Crutch skid B type 1**
  - Vertical support only (V)
  - Approx. 60°

- **Crutch skid B type 2**
  - Vertical and lateral support (V and H)
  - Approx. 30°

- **Crutch skid B type 3**
  - Vertical and lateral support (V and H)
  - Approx. 20°

Pipeline string configuration: skid layout
**External air temperature**

→ triangular variation during the day ($T_{air}$)

**Maximum thermal gradient**

→ $\Delta T = 30 \, ^\circ C$ (difference between the external air temperature and the maximum temperature measured on the pipeline side exposed to the sun)

**Thermal gradient**

→ linearly variable in horizontal direction (two side of the pipe)

**Thermal load conditions**

→ discretized on temporal basis (in function of time and construction length)

- **Condition 1**
  → $\Delta T$ constant during the entire working day, from 7 am to 7 pm, it is the most conservative and severe condition

- **Condition 2**
  → thermal load acting on the string at mid-day, when only half of the string is presumed to be welded

- **Condition 3**
  → thermal load acting on the pipeline at day’s end when the entire string has been welded
Introduction & input data

Stability analysis of the *crutch skids*

Global analysis of *pipeline string* and evaluation of the forces acting on the skids

Analysis of *skid stability improvement*

Conclusion, Recommendations, Developments
FOCUS
Investigate the performance levels of crutch skids type B to verify their stability relatively to their structural features and geometries

MODELLING
Analyses of the crutch skids were carried out using FEM Abaqus Software, modelling each diagonal block assembly as a single overall element (Friction coefficient “wood/wood”: 0.5 / 0.6)
The analyses were performed by imposing the vertical action V and determining the horizontal action H until the model loses convergence
The points inside the yellow area represent the “stable conditions domain” for the skid. If a solicitation (V, H) is inside the yellow area the skid is in stable condition.

- Crutch skid B type 1 has a level of stability lower than crutch skids B type 2 and 3 (max allowable H/V approx. 0.15)
- Crutch skid B type 2 has an intermediary level of stability (allowable H/V range from 0.35 to 0.25)
- Crutch skid B type 3 performs in a maximum level of stability (max allowable H/V approx. 0.35)

Operational convenience of using crutch skids B type 3 instead of crutch skids B type 1 or 2
KEY MAP

- Introduction & input data
- Stability analysis of the *crutch skids*
- **Global analysis of pipeline string** and evaluation of the forces acting on the skids
- Analysis of *skid stability improvement*
- Conclusion, Recommendations, Developments
GLOBAL ANALYSIS OF PIPELINE STRING AND EVALUATION OF THE FORCES ACTING ON THE SKIDS

FOCUS
Investigation of skid reactions (V and H) under pipe self-weight and thermal conditions, considering different pipeline string configurations

MODELLING
Analyses of the crutch skids were carried out using FEM using Abaqus Software, for a linear pipeline string on flat ground level and in the absence of friction at the pipe-wood interface.

Thermal loading 1 → the last two spans are the most solicited, involving the last three crutch skids (maximum H/V ≈ 0.45 at KP 1020 m)
Thermal loading 2 → the first crutch skid is the most solicited (maximum H/V ≈ 0.04)
Thermal loading 3 → the middle crutch skid is the most solicited (maximum H/V ≈ 0.06 at approx. KP 600 m)
GLOBAL ANALYSIS OF PIPELINE STRING AND EVALUATION OF THE FORCES ACTING ON THE SKIDS

STABILITY OF THE CRUTCH SKIDS FOR LINEAR PIPELINE STRING

Thermal condition 1
- crutch skid B type 3 is operationally convenient with respect to types 1 and 2
- crutch skid B type 1 has the worst performance in terms of stability
- for a less severe $\Delta T = 20^\circ C$, both crutch skid B types 2 and B type 3 are suitable

Thermal conditions 2 and 3
- all crutch skids are stable

<table>
<thead>
<tr>
<th>Crutch skid type and stability condition</th>
<th>Pipeline string configuration</th>
<th>Thermal loads</th>
<th>Support reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 Stable</td>
<td>B2 Stable</td>
<td>B3 Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Unstable</td>
<td>Unstable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Unstable</td>
<td>Unstable</td>
<td>Unstable</td>
<td>Linear</td>
</tr>
<tr>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Unstable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Unstable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Unstable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
<tr>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Linear</td>
</tr>
</tbody>
</table>

Tabular results - stability of the crutch skids
GLOBAL ANALYSIS OF PIPELINE STRING AND EVALUATION OF THE FORCES ACTING ON THE SKIDS

CONTACT INTERACTIONS MODELLING

For crutch skid B type 3 two detailed FEM models have been developed in order to assess the effective response of the whole system constituted by pipe plus support, including the interaction (friction) between the pipeline and the crutch skid:

- **MODEL 1** → actual contacts between pipe and wood blocks have been modeled.
- **MODEL 2** → friction pipe - wooden skid and complete geometry of the system (pipeline plus skid).

- Modelling of contacts reduces H/V acting on the last crutch skid B type 3 from 0.45 (considering the same load conditions but without pipe-skid contact modelling) to approx. 0.35 (≈20% reduction)
- A similar reduction of H/V is expected both for the other thermal loading conditions and for the other types of crutch skids B
- All the crutch skids are stable for thermal conditions 2 and 3 in terms of both strength and deformation.
- Introduction & input data
- Stability analysis of the *crutch skids*
- Global analysis of *pipeline string* and evaluation of the forces acting on the skids
- Analysis of *skid stability improvement*
- Conclusion, Recommendations, Developments
FOCUS
Investigate possible enhancements for crutch skid stability, by restraining the wooden stocks with elastic bands (simulating cargo straps usually available on site)

MODELLING
Calculations were carried out with Abaqus software using the defined previous structural model. Sensitivity analyses were conducted considering different restraint system stiffnesses (modulus of elasticity from 500 to 50,000 MPa).

Results of FEM analysis - stresses, displacements and rotations when failure occurs (Abaqus)
ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT

STABLE CONDITIONS DOMAINS

- Straps have a significant improving effect on crutch skid B types 1 and 2, doubling their stability domain.
- Crutch skid B type 2 is the most stable support among the restrained configurations, providing \( H/V = 0.45 \).
- Straps do not affect the stability of crutch skid B type 3; the performance behavior of crutch skid B type 3 is strictly related to the assessment of the whole configuration.

- Bandaging is a good technique to enhance pipe support stability.
- Since the practice can be time-consuming and costly, below an expected loading level, the best practice is the correct assembly of the stocks.

Stability Analysis for Crutch Skid B Type 1

- WITH Bandaging
- NO Bandaging

Stability Analysis for Crutch Skid B Type 2

- WITH Bandaging
- NO Bandaging

Stability Analysis for Crutch Skids B Type 3

- WITH Bandaging
- NO Bandaging

Comparison between stability domains with / without bandaging.

EFFECT OF MODULUS OF ELASTICITY (CRUTCH SKID B TYPE 1)

- Base Case
- Restraint System E=500kPa
- Restraint System E=2500kPa
- Restraint System E=5000kPa
- Restraint System E=20000kPa
- Restraint System E=50000kPa

Sensitivity analysis for strap elasticity.

- Effect of strap elasticity is negligible.

Geneva, October 17
KEY MAP

- Introduction & input data
- Stability analysis of the *crutch skids*
- Global analysis of *pipeline string* and evaluation of the forces acting on the skids
- Local stability analysis of *pipe & support* on the ground
- Conclusion, Recommendations, Developments
Wooden cribbing blocks are widely used to support the pipeline string temporarily during construction. Depending on the environmental circumstances, transversal forces may act on the pipeline leading to the possibility of critical stability conditions for the pipe.

- In terms of stability, crutch skid B type 3 is more convenient than crutch skid B types 1 or 2. Therefore the use of crutch skid B type 3 is recommended respect to the others.

- As potential improvement of skid performance level, wooden stock bandaging has been evaluated for the three types of crutch skids. The method has a significant stabilizing effect for crutch skid B type 1 and 2, while has no effect for crutch skid B type 3.

- Skid failure mechanism is widely attributable to geometrical configuration of the wooden stocks. Therefore it is recommended a correct assembly of the wooden stocks.
The study has been carried out assuming simplified conditions (linear pipeline string, flat ground surface, etc.) that are not the most conservative. In particular, for severe climatic conditions ($\Delta T=30^\circ C$) it is recommended a proper working schedule in order to left the pipeline string on wooden stocks as little time as possible (a working day at maximum).

According to SAIPEM standard safety approach, in order to limit the thermal expansion effects, each daily pipeline string should not be left on wooden stocks but secured (e.g. DE-SKIDING by replacing temporary stock with soil berms at the most solicited progressives).
Stability conditions of pipeline string on wooden stock supports have to be further investigated considering other possible cases, such as:

- pipeline string configurations with induction bends in different positions → Journal of Pipeline Engineering (9/2017)
- sloped sections
- additional geometrical assemblies for wooden cribbing blocks
# ANÁLISIS DE LAMINAS DE MADERA TEMPORÁNEAS PARA SOBREPIRAMIENTO DE EXCAVACIÓN

**ANALYSIS OF TEMPORARY WOODEN CRIBBING BLOCKS FOR PIPE SUPPORT**

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ms. Angelina Parlato</td>
<td><a href="mailto:angelina.parlato@saipem.com">angelina.parlato@saipem.com</a></td>
<td>SAIPEM, Italy</td>
</tr>
<tr>
<td>Mr. Agostino Napolitano</td>
<td><a href="mailto:agostino.napolitano@saipem.com">agostino.napolitano@saipem.com</a></td>
<td>SAIPEM, Italy</td>
</tr>
<tr>
<td>Mr. Diego D’Alberto</td>
<td><a href="mailto:diego.dalberto@saipem.com">diego.dalberto@saipem.com</a></td>
<td>SAIPEM, Italy</td>
</tr>
<tr>
<td>Mr. Salvatore Morgante</td>
<td><a href="mailto:salvatore.morgante@saipem.com">salvatore.morgante@saipem.com</a></td>
<td>SAIPEM, Italy</td>
</tr>
<tr>
<td>Mr. Angelo Rosato</td>
<td><a href="mailto:angelo.rosato@39-italy.it">angelo.rosato@39-italy.it</a></td>
<td>++39, Italy</td>
</tr>
</tbody>
</table>

**References:**

*Engineering assessment for temporary wooden pipe support, D. D’Alberto, A. Napolitano, S. Morgante, A. Rosato. Journal of Pipeline Engineering, September 2017*