THE DESIGN AND CONSTRUCTION OF THE CHINIPAS SLOPE PIPELINE CROSSING
DESCRIPTION OF THE INITIATIVE

20th IPLOCA
IPLOCA Environmental Award sponsored by Shell

Fano, Italy - May 2016
A LEADING GLOBAL OIL & GAS SERVICES PROVIDER

Operating in more than 60 countries
- 45,000 employees from >120 nationalities
More than 20 engineering and project execution centers worldwide
11 fabrication yards in 5 continents

REVENUES
2014 12.9 B€
2015 guidance 11÷12 B€

BACKLOG
June 30, 2015 19.0 B€
Saipem Business Profile

AN IMPRESSIVE TRACK RECORD OVER MORE THAN 60 YEARS

Engineering & Construction

- Designed and built:
  - More than 100 grass roots complexes, 2,000 process units
  - Over 130,000 km of land pipelines, sealines and trunklines
  - In the last decade, more than 100 offshore EPIC projects,
    including groundbreaking deepwater achievements

Drilling

- Drilled over 7,300 wells, of which 1,800 offshore
GLOBAL PRESENCE WITH A MULTILOCAL EMPHASIS
**Saipem Business Profile**

**HSEQ Top Saipem Priority**

*Lost Time Frequency Rate* is the ratio between the number of incidents with loss of working days and total worked manhours (x 1,000,000).

*Total Recordable Incidents Frequency Rate* is the ratio between the number of total recordable incident and total worked manhours (x 1,000,000).
HSEQ Top Saipem Priority

The design and construction of the Chinipas slope pipeline crossing, 20th IPLOCA environmental award.
SAIPEM has been awarded from TRANSCANADA the engineering, procurement and construction of “El Encino - Topolobampo” 30”, 540km Natural Gas Pipeline Project in Mexico. The pipeline runs in a West-South West direction perpendicularly crossing the “Sierra Madre Occidental”, a mountain range characterized by uneven morphology with deep and narrow valleys and steep slopes.

The present case study is related to the western side of the Sierra Madre Occidental (SMO), known also as Sierra Tarahumara, along the Eastern valley-side of the Chinipas River between the Chihuahua State and the Gulf of California.
The area is characterized by abrupt changes in elevation, alternating between narrow, faulted mountain chains and flat arid valleys. The area is categorized by volcanic plateau hanging at elevation from about 1050 up to 1500 m a.s.l., interrupted in its south-western edge by a series of rocky cliffs (escarpments) with heights ranging from 150 to 200 m. The pipeline route has to overcome such high steep slope.
After assessing all possible alternatives such as pipeline rerouting, gentle slope crossings in open trenches, the idea was to study a trenchless crossing by mean of raise borer technique;

Solution proposed had the aim of preserving the landscape, environment while providing a suitable method to cross the cliff.
✓ Since the area was nearly inaccessible, a remote sensing process based on the Structure from Motion (SfM) technique was used jointly with University of Urbino for the three-dimensional reconstruction of the outcrop of the cliff;

✓ Oblique images were acquired through a digital camera at high resolution. The images were georeferenced by connecting the camera to a GPS with accuracy metric. The images were taken from an helicopter that flew over the whole area at different points at a height of about 100 m above the ground.
Solution

✓ Over a set of images of the same object, the SfM algorithm allows to extract the 3D coordinate of the detected points and to generate points cloud (Westoby et al., 2012). In the surveyed outcrop a cloud of 11*10E6 points were detected.
From the point cloud a fully rendered 3D geological model of the whole outcrop was generated, providing the possibility to extract the geometries of the structural discontinuities;

rocky slope stability analyses were performed starting from the information regarding the spatial geometries of the fractures (ISRM, 2007).
Rock fall propagation analysis were conducted using a combined approach of deterministic and stochastic type (probabilistic process-based model rockfall trajectory) based on the method proposed by Dorren (2012) and on Rockyfor3D software that allows, at different scales of study, to simulate in three dimensions the trajectories of the individual rock blocks collapsed.

This study allowed to properly evaluate the geology, geomorphology and rock mechanics of the area, with suitable standard methodologies that reduce the uncertainty in the interpretation of the rock mass characterization to find out the best location to perform the raise borer.
Implementation

✓ Design of the trenchless crossing was performed and shared with Project team (Client and Saipem) for approval in 2014.
✓ Since was considered (as far as the Authors know) the first raise borer ever executed for a gas pipeline in Mexico, Client was skeptical;
✓ Saipem raise borer reference list was provided and site visit to raise boring machine subcontractor performed;
✓ Site preparation started in January 2015 by building the access track from the bottom side of the ridge and grading a 1.500 m² platform for the stocking of line pipes, equipment and excavated material
Implementation

- Approx. 138 m length sub-vertical gallery;
- Approx. 100 m length horizontal tunnel with a cross section of 3,5 x 3,5 m;
- 11” pilot hole, which reached the tunnel and where a reamer head was then installed and lift up creating a 56” diameter shaft;
- 48” Casing Pipe 9,54 mm WT;
- Collars: APC 30” x 48” Clear Bell spacers;
- 83 Tons Hydraulic Drum Winch.
Aerial view of the Chinipas slope and the construction areas
Pipeline raise borer has been designed and executed to perform the trenchless crossing of the Chinipas Slope for the first time in Mexico.

Since the area was almost inaccessible and very remote, a remote sensing technique based on the procedures Structure from Motion (SfM) for the three-dimensional reconstruction of the outcrop of the cliff has been adopted jointly with University of Urbino.

The SfM technique allowed to conduct a satisfactory identification of main system of discontinuities and following kinematic analysis and rock-fall modeling to find out the best location of the raise borer and to optimize the design in terms of inclination, depth, length, etc...

Particularly, it has been possible to maintain the bore into the rock with better geomechanical features avoiding frequent lithological variations potentially critical in the process of raise boring.

The mouth of the tunnel has been optimized bringing it in proximity of outcropping rock avoiding the body of debris present at the base of the slope avoiding major excavation works or supporting structures.

The complete success of the raise borer has achieved all the objectives in terms of minimization of all environmental impacts.
Achievements

- SUSTAINABLE: Minimization of environmental impacts
- INNOVATIVE: First time geomechanical study using a remote sensing process
- TECHNOLOGICAL: First time in Mexico
- SAFE: No injuries
Long Term Planning

✓ Raise Boring technique is a valid alternative in pipeline construction to minimize pipeline construction impacts when crossing sub-vertical slope or sensitive environmental areas;
✓ Local regulation do not necessary provide restrictions in performing open cut crossing (such is the case of Mexico), but promotion of trenchless method should be encouraged (if technically feasible) since can provide a really step forward in pipeline projects;
✓ A safe and reliable design of a raise borer in rock cliffs cannot prescind from geological and geomorphological studies to assess the geohazards related to the specific crossing;
✓ Generally, spatial geometries of the fractures can be collected during structural surveys, which in steep and remote rocky cliffs are time demanding and highly consuming in term of human and economic resources;
✓ In the Project, remotely sensed data integrated with GIS have provide equivalent information to perform. The SfM technique allowed to conduct a satisfactory identification of main system of discontinuities, following kinematic analysis and rock-fall modeling. The approach allowed a quantitative estimation of the attitude of fractures delineated exploiting three-dimensional virtual reconstruction leading to an optimization of the Raise Borer geometry;
✓ The initiative can be extend by the use of new drones survey and improvement in close range photogrammetry analyses.