DON'T PUT YOUR PIPELINE PLANNING TO BED WITHOUT A PILLOW

Geoff Connors, President & Founder, PipeSak Inc., Canada, discusses the importance of supporting a pipeline for the duration of its lifecycle.

During the planning and engineering phases of most new pipeline projects, one needs to consider how best to support this expensive new pipeline in areas of rock or stone. Even with tough, modern pipeline coatings, additional protection for the pipe is often necessary. A pipeline's safety and long-term integrity depends on it.

Historically, additional external pipe protection is achieved through adding either a significant layer of sand or select backfill above and below the pipeline (sand padding) and/or by covering the pipe with a high impact-resistant, poly-type rock shield just prior to installing.

To accommodate sand padding, some form of intermittent support of the pipeline is required to elevate the pipeline off the trench bottom to allow the sand to flow evenly around the pipeline. Similar intermittent support is also a recommended practice when using poly-type rock shields to keep the pipeline from fully resting on trench rocks.

To date, methods of intermittent pipeline support involve the use of sand piles, sand bags, spray foam or pre-formed foam pillows – each with serious drawbacks, particularly with today's larger, thin-walled pipelines.

Figure 1. SPPs are engineered to support any size pipeline. The structued pillows have multiple uses both in and out of the trench.

Figure 2. SPP design meshed.

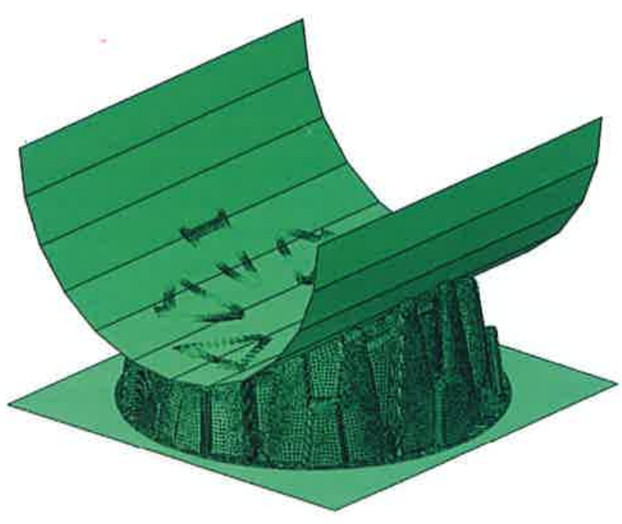

Figure 3. SPP analysis set-up with a 36 in. pipe.

With long-term pipeline integrity continuing to be a significant concern for all pipeline owners, a more 'engineered' method of support is needed – something that can be relied on for the life of the pipeline. The structured pipeline pillow (SPP) achieves this criterion – and more.

SPPs are injection moulded and made from high strength, environmentally inert polypropylene or polyethylene resins – some with glass fibres to increase durability in differing temperature conditions.

Designed to support any size pipeline, SPPs are most helpful with larger diameter, heavier pipelines. One will safely carry a single 40 ft joint of heavy wall pipe filled with hydrostatic test water (Figure 1).

In their extended stacking mode, the larger SPPs work well as an alternative to wooden skids for many situations such as pipe stockpiling; stringing along the right-of-way (ROW); and even for some low level skidding during the welding process.

Current pipeline support methods

The common methods for holding the pipe up off the trench bottom in rocky or stony areas are: loose sand piles/pillows; sand bags; spray-in foam; and preformed foam pillows – each with different disadvantages.

Sand piles/sand pillows

For larger pipelines, sand piles are difficult to install and a major contributor to pipeline ovality and denting when improperly placed. Additionally, loose sand tends to migrate easily as groundwater percolates back into the trench lessening its ability to support the pipeline.

Sand bags

These require hand placement to achieve proper, level support for the pipeline. In open trenches, this can be time consuming and unsafe. Improper placement can again cause the pipe to oval or dent.

Spray-in foam

Spray-in foam shields cathodic protection currents wherever it touches the pipe. Newly constructed pipelines full of hydrostatic test water and 1 m cover can cause foam to compress excessively.

Preformed foam pillows

These pillows are light and easily placed, but can float out of position and compress or crack under heavy loads. As with all foam, cathodic shielding is always a concern.

In summary, both spray and pre-formed foam pillows remain the most common method of in-trench pipeline support. The obvious fact that foam shields cathodic protection (CP) systems has been consciously overlooked due to the apparent support abilities of foam. This has been particularly important for large diameter pipelines with high D/t ratios, which are most susceptible to ovality and denting.

The structured pipeline pillow

Design

The following criteria were considered for the ideal pipeline pillow:

- Light enough to be handled individually.
- Stackable for easy transport.
- UV resistant.
- Easy to install – a worker is not required in the trench for installation.

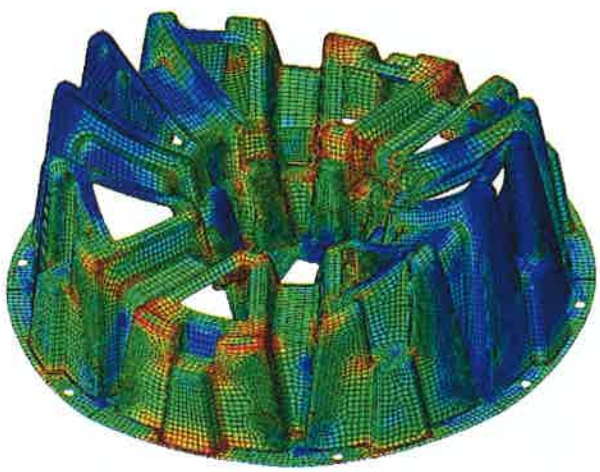

Figure 4. FEM modelling-loaded.

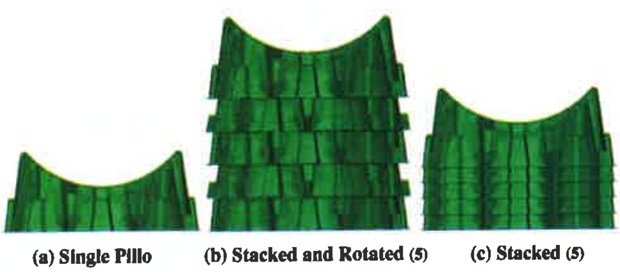

Figure 5. SPP stacking configurations.

Figure 6. Loading a SPP.

- Resist flotation.
- Strong enough to hold a pipeline filled with hydrostatic test water.
- Contact area with the pipe surface should be porous enough to allow free flow of groundwater and cathodic protection currents yet large enough to keep coating stresses low.
- Resistant to a wide range of chemicals (pH) found in soil.
- Inner cavities accessible to soil inflow over the long-term.
- Must maintain pipe clearance off the trench bottom for the life of the pipeline.

Engineering software was utilised to develop and initially analyse different designs, working through numerous iterations before honing in on a design that met all the criteria.

Once a basic design was developed, a conical shape, which includes outer and inner supporting walls, analysis was carried out utilising finite element tools (Figure 2).

The finite element modelling (FEM) analysis consisted of simulating a pipe loaded to varying weights applied to the SPP (Figure 3). From the results engineers were able to identify the highest stress points and the areas that underwent the most deflection and alter the design accordingly. These iterations allowed the SPP to handle increased loading while reducing the overall weight.

Additional analysis to confirm the initial, in-house analysis was carried out by independent consultants applying the more advanced the finite element software program ABAQUS (Figure 4).

As the design was further tweaked, physical models were fabricated utilising rapid prototyping tools. With physical models in hand, it was easy to envision the SPPs potential for use outside the trench, as an alternative to wooden skids for many applications. With this realisation, load bearing, stacking shoulders were incorporated into the design. This allows for a stable, safe stacking configuration in an elevated position. The stacking shoulders also helped to increase the overall strength of the design (Figure 5).

The SPP was designed to partially flex under the weight of the pipeline. In areas where the pipe and the trench bottom do not meet, handles were incorporated into the design to give the contractor the option to strap SPPs to the bottom of the pipe to ensure contact is maintained during backfilling. This same strapping method can be utilised in areas of deep excavation to attach the SPPs prior to installing the pipe section.

Full-scale testing

Full-scale samples for use with 914 mm OD (36 in.) pipe were manufactured and tested in a local pipe yard.

One 12 m joint of 914 mm OD, 19 mm WT pipe (40 ft, 36 in. OD, 0.75 in. WT) was balanced on a single SPP with a total load of 5200 kg (11 460 lb). To simulate the potential load from hydrostatic test water, two geotextile fabric pipeline weights each weighing 4082 kg (9000 lb) were installed on the

Figure 7. SPP skid replacement outside of trench.

Figure 8. SPP in trench.

pipe on either side of the SPP. No deflection of the SPP was observed (Figure 6).

To take the SPP to failure, additional loading was required – two 1590 kg (3500 lb) concrete blocks were placed on top of the geotextile fabric weights. At this time the single SPP slowly collapsed indicating failure. Total load applied to one SPP was 16 544 kg (36 473 lb).

As material compositions and design were further refined, additional and more controlled testing proved the SPPs could withstand even higher loading. The addition of glass fibres at specific percentages has also helped create a more ductile SPP while maintaining its strength.

Construction field test

Before going to market, 100 SPPs were trialled on a short section of El Paso's new Ruby Pipeline (1067 mm OD, 16 mm WT) that was completed in 2011.

Although supplied to support the pipeline through approximately 300 m of extremely rocky trench, the pipeline contractor also utilised the SPP as a replacement for wooden skids outside the trench. SPPs were used at single height during the pipe stringing phase and in an elevated and stacked position throughout the set-up and welding phase (Figure 7).

Following the stringing and welding, the SPPs were reused in the trench. Spacing was kept similar to the foam pillows – which were approximately one every 3.7 m (12 ft) – even though the load bearing capacity of an SPP far exceeds that of a foam pillow (Figure 8).

SPPs are designed to be installed with an installation tool, which is similar to a 4.8 m long, 2 x 4. Each SPP has a centre hole with a rectangular cross-section complimentary to that of the installation tool. The installation tool is placed at the bottom of the trench where the SPP is required. The SPP is then mounted onto the

Sand padding around the pipe does not ensure long-term isolation for rocks and stones

Typical pipeline engineering practice has always considered intermittent pipeline supports to be a temporary measure – with long-term pipeline support coming from the sand padding. However, today more is known about why this theory is 'sinking'.

Groundwater will always follow the path of least resistance – which is very often a newly constructed pipeline trench. When the rare 'opportunity' arises that a specific stretch of pipeline must be exposed for repair, more often than not, it is discovered that the original sand padding has either diluted with the surrounding stone – or is gone completely. The passage of groundwater over the years often causes the light sand to migrate away from the pipeline – replaced by the heavier, sharper stones above it. Since this is a gentle, slow process, one would not expect the stones above and around the pipe to be a serious threat. However, now the 'temporary pipeline supports' become a more critical element in the pipeline's long-term integrity. If the pipeline is allowed to fully settle down onto the rocky trench bottom, the risk of damage is far greater. The 6 o'clock position of the pipe will be exposed to a fully consolidated, hard, rocky trench bottom with the pipes weight, its contents and above backfill all contributing to the downward force. Ovality, denting and gouging of the pipe are real concerns.

Pipeline supports should no longer be considered 'temporary'. They could possibly be the only long-term support the pipeline will have.

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Figure 9. SPP installation in trench.

Figure 10. SPP being used in a fabrication application.

user end of the installation tool, flange side first, and slid into position (Figure 9).

In the trench, SPP performed perfectly, not only supporting the pipeline but also keeping it centred in extremely rough trench conditions. Prior to placing the pipeline into service, geometry tools were run through the pipeline with no evidence of ovality or dents in the area of the SPP.

Another added benefit from the contractor's perspective was the decreased labour component when using SPPs. Out of the trench, SPPs can be quickly and easily stacked with less than half of the labour (when compared to wooden skids). In the trench, SPP can be quickly slid into place and resisted flotation when small amounts of groundwater trickled in.

Case study

Since the Ruby Project, SPPs have been slowly introduced to the pipeline market. They are being used for small to large diameter pipelines as well as in fabrication yards – SPP are easy to handle and can be quickly stacked in the limited area of a welding shop or yard (Figure 10).

After seeing the SPPs featured in media reports, Bluewater Constructors, Inc. (BWC), a Merit Shop, Texas Corporation, decided to use them on multiple 20 - 36 in. pipeline projects. "Bluewater has found this innovative product to be a real winner," said Tom Skinner, a Bluewater Superintendent. The company has been providing both engineering and construction services for natural gas compression projects on major interstate pipelines.

"Our welders have found SPPs to be lightweight and easy to set up. SPPs hold the pipe securely so they can work with the pipe without harming the coating or fear of the pipe rolling off. Using the SPP has even reduced our need for wooden skids," said Skinner. From Bluewater's perspective, using a SPP has simplified its processes. "Using SPPs has even saved money on our bottom line and best of all the pillows are safe," Skinner added.

Conclusion

The industry is ready for a change. Ensuring pipeline integrity is maintained throughout its lifecycle makes not only good engineering sense but economic sense as well. The new structured pipeline pillow helps industry take another step closer to ensuring all pipeline materials that 'live' with the pipe over its lifetime, are 'engineered'.

When designing a new pipeline, operators should insist that fully engineered products are used whenever possible – and supply the appropriate specifications in the contract documents. SPPs are now available for all pipeline sizes.

In summary, structured pipeline pillows:

- Stack tightly for transport.
- Are light enough for installation from outside the trench.
- Have side handles that can accept a rope to loosely strap the SPP to the bottom of the pipe prior to installing the pipe in areas of deep excavation.
- Resist flotation when ground water is present making them easy to keep in place.
- Help ensure the pipe is centred in the trench, which is important in rocky trenches.
- Will never biodegrade – maintaining long-term pipe clearance above rocky trench bottoms.
- With their 90° support, ovality and denting concerns are greatly reduced.
- Allow cathodic protection an easy path to the pipeline.