LOW-TEMPERATURE THIXOTROPIC CEMENT DESIGN OVERCOMES SURFACE SECTION DRILLING CHALLENGES – DEEP GEOTHERMAL EXPLORATION PROJECT, JAVA - INDONESIA

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ABSTRACT

A low-temperature thixotropic cement design was utilized to successfully overcome surface drilling challenges in a deep geothermal exploration well in Java island - Indonesia. This solution was provided for the second exploration well after unexpected surface challenges were encountered during drilling of the surface hole section, where hole destabilization and total loss of circulation occurred because of unconsolidated Andesitic Lava Boulders, also encountered in the first well. The other challenge was a low surface temperature because of the high elevation of the well pad, which was higher than 2,000 feet above sea level.

Before this low-temperature thixotropic cement design was implemented, several cementing plugs had been pumped to stop the losses and stabilize the formation, with no significant result. Therefore, a decision had been made to perform a plug and abandonment (P&A) operation on this first well.

To avoid this P&A outcome, a low-temperature thixotropic cement was designed to have a slurry that would enable the operator to stabilize the surface hole so that the surface casing could be run and set at bottom-hole. The processes involved leading up to the utilization of this effective slurry design to stabilize the hole are listed below:

- Met with all parties to discuss options for thixotropic material that could be added to the slurry
- Selected two possible thixotropic additives (Material A and Material B)
- Performed a total of 58 lab tests to determine the thickening time and thixotropic properties of each slurry, as well as their different weights, concentrations, and temperatures
- Selected the slurry that had a thickening time below 90 minutes

Upon successfully inventing the most effective slurry, the operator was able to drill the surface section to target depth, and the surface casing was set at maximum depth. The drilling was continued in the well to a planned total depth (TD) at 11,300 feet. At the time of the writing of this publication, this well was the deepest geothermal well in Indonesia.

1. WELL OVERVIEW

Well X-2 is the second well drilled from the Wellpad X as part of the Deep Geothermal Exploration campaign in Central Java. The well was drilled vertically using a 2,000 HP rig. The project was executed in Q1 2018 with an IPM model under Halliburton Project Management.

Well X-2 is located on the same pad as Well X-1 (first well) with cellar distance of 7.5 m center to center. Well X-1 was P&A due to drilling difficulties experienced in the surface stage. Drilling difficulties included total loss of circulation and hole stability issues because of unconsolidated Andesite Lava Boulders. These drilling challenges led to more than 60% of non-productive time.

The X-2 well was designed and completed as a big geothermal hole with a 13-3/8” production casing.

2. DRILLING CHALLENGES

With very limited to no sub-surface offset well data, the first well was drilled with unexpected drilling challenges, resulting in a harsh drilling environment with high torque, vibrations during drilling and a stuck pipe. The stuck pipe event causing the BHA left in hole, sidetrack and abandonment.

2.1 Surface Losses during drilling the 1st well

Losses was observed right below the conductor during the rig endurance test. Several cementing plug jobs were needed to stop the losses before drilling started (spud-in). During drilling, total loss of circulation was experienced from 30 ft below the conductor. A cementing plug with 20 bbls of 15.8 ppg slurry was performed before drilling continued with partial loss of circulation from 250 ft to TD.

Total loss of circulation was observed again in the section from 250 ft to TD and it was decided to continue blind drilling in the section from surface to TD.

2.2 Hole Stability Issue

Hole stability issues were experienced during the drilling of the surface hole section because of unconsolidated Andesite Lava Boulders. High torque, pipe stall and high vibrations were observed during drilling and tripping occurred with Directional BHA. To minimize the impact of lost-in-hole value, it was decided to run a reaming BHA to clean out the hole prior to running the surface casing. Stuck pipe occurred during the clean out run. Refer to Figure 2 for details of problems during the drilling of the original hole. It was decided to manually back-off the string after there was no progress on the stuck pipe freeing operation. The fish was left in hole after 136 hours of the fishing operation and sidetracking of the well. Nine cement plug jobs were performed to plug the sidetrack from 30 ft to below the conductor.

The sidetrack surface hole was drilled under total loss of circulation. Four cement plugs job were performed in an attempt to stop total loss conditions and to stabilize the formation with no result. Because of high torque, over pull, and stuck pipe while drilling it was decided to TD the section at 250 ft, earlier than the planned section TD. Refer to Figure.3 for details of problems during the drilling of the sidetrack hole.

The surface casing was run with a casing drive system, but the casing was set 60 ft above the bottom. The cementing job was performed with no return and followed by ~2,100 bbls cement slurry pumped during 11 top-up jobs.

Drilling was continued with an intermediate hole section and total loss of circulation was observed after drilling out the rat hole. Drilling then continued with no return (blind drilling) to the planned intermediate casing TD but with significant hole problems – refer to Figure 4. The effect of hole problems was seen in the condition of the bit and stabilizer at the surface.

To increase the possibility of having the intermediate casing set at the TD, the casing was run with 17-1/2” x 13-3/8” drill shoe and casing drive system. An obstruction was observed only a few feet below the surface section. After several hours with no progress on reaming down the casing it was decided to POOH the intermediate casing to surface. The bit shoe was found to be severely worn out.

A clean out run was made with no luck as the clean out BHA was stuck at a hundred feet below the surface casing shoe and was not able to be fished out. Thus, the BHA was left in hole.

As a result of the above difficulties, it was decided to plug and abandon Well X-1.

Figure 1: Worn out or ring out drill shoe and unconsolidated Andesitic Lava Sample that was caught by Fishing Tools

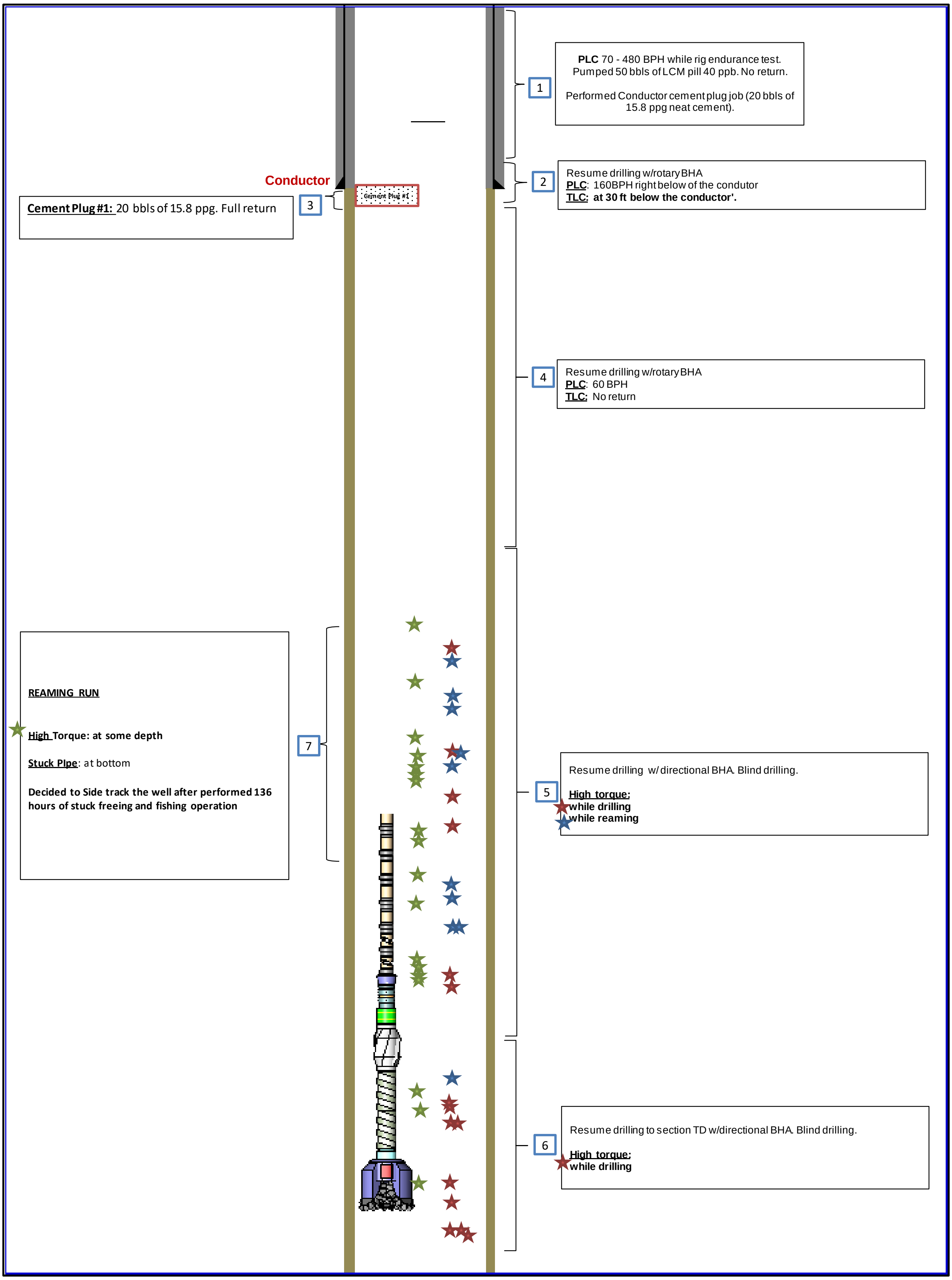

Figure 2: Hole problem summary – Surface Losses, Hole Stability Issue and Stuck Pipe – Surface Section – Original Hole

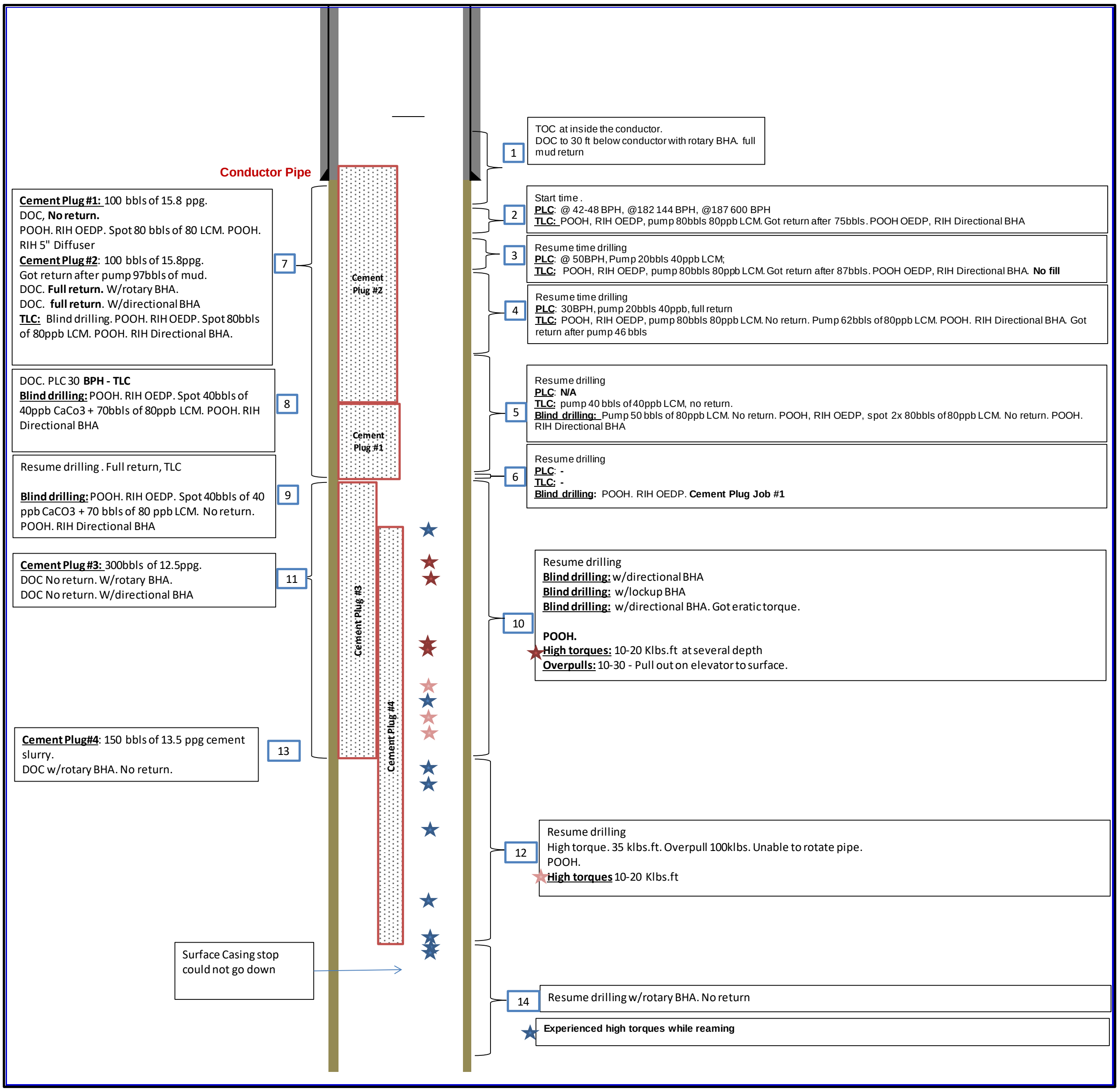

Figure 3: Hole problem summary – Surface Losses and Hole Stability Issue– Surface Section – Sidetrack Hole

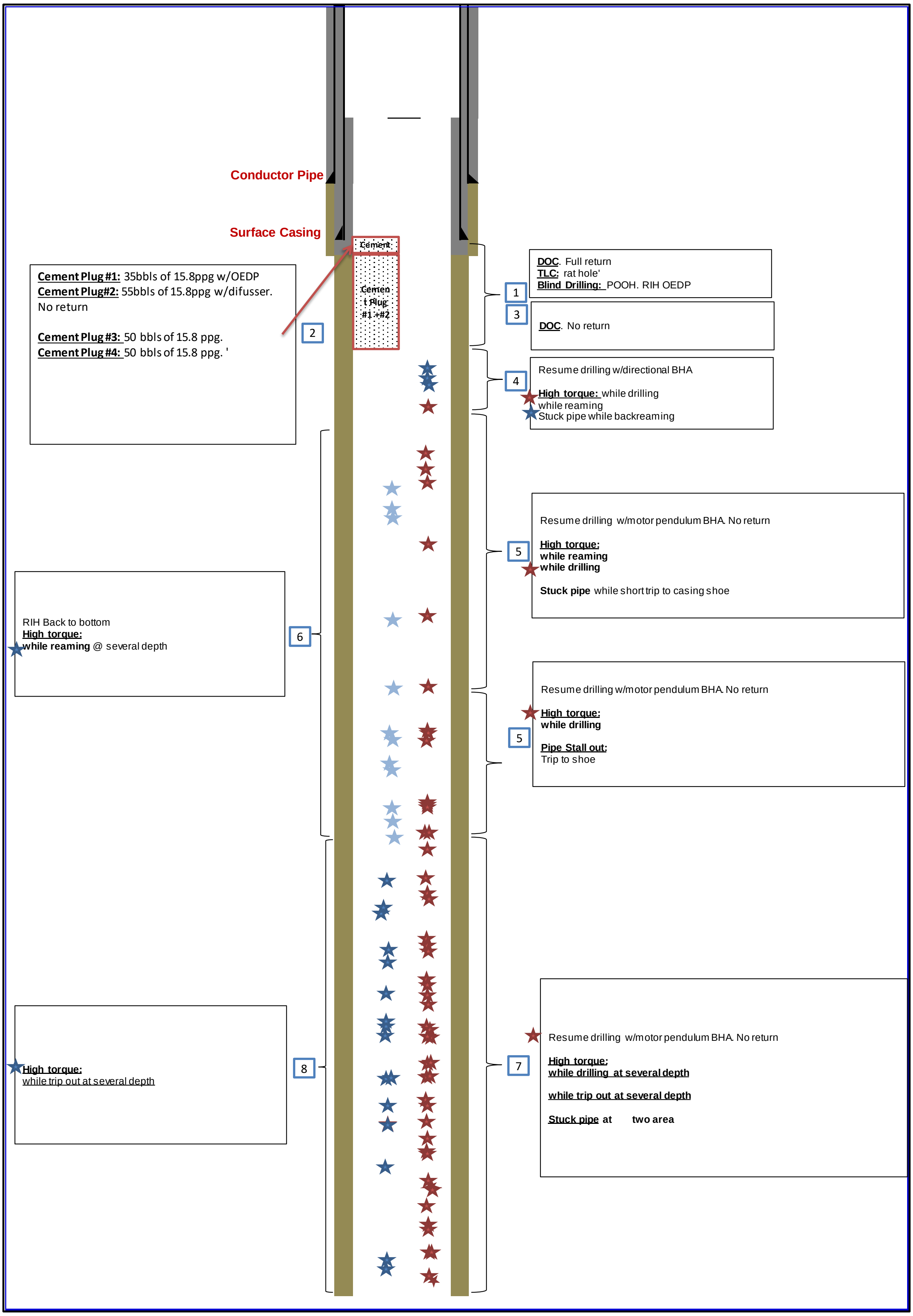

Figure 4: Hole problem summary – Total Loss of Circulation and Hole Stability Issue– Intermediate Section

3. TAILORED SOLUTION

Tailoring a cement slurry to stop the losses and stabilize the surface hole section from unconsolidated Andesitic Lava Boulders is very challenging because cement LCM are designed to effectively stop losses with small pore size due to the limitations of LCM particle size and maximum concentration. Cement LCM with the largest particle size that was available can pass through a 4mm nozzle and the gap between Andesitic Lava Boulders in this area was larger than 4mm resulting in ineffectiveness of using cement LCM.

Another common method in stopping losses is by reducing the cement slurry density to reduce the hydrostatic pressure applied to the formation. But in this location the low well temperature was delaying the development of the strength of the low-density cement slurry thus preventing it being able to stabilize the hole.

Several attempts to stop the losses in the previous well with cement LCM and low-density cement were unsuccessful, and therefore thixotropic cement slurry was proposed as the solution for this well. A thixotropic slurry was chosen because of its shear thinning property that helps the slurry to still be pumpable and able to flow into the loss zones while it can gel-up quickly once in static conditions. This property has the benefit of not only curing the losses but also stabilizing the hole.

Due to low surface temperatures, the cement slurry needs to have the thixotropic ability in a low temperature environment.

3.1 Material Selection

A low temperature thixotropic cement slurry is designed by adding a thixotropic additive to the slurry. In selecting the thixotropic additive several factors need to be considered, such as the additive temperature range, job execution or cement blending procedure, and material availability. With these considerations, Material A and Material B were selected to be used as thixotropic additives.

Table 2: Material A and Material B Properties.

Material	Physical State	Temperature Range
Material A	Solid/Powder	40-170°F
Material B	Liquid	35-140°F

3.2 Cementing Lab Test

The final compositions of Material A and Material B were finalized after running several lab tests by testing the rheological properties, thickening time, and the compressive strength with an ultrasonic cement analyzer.

These compositions were chosen because they have the shortest thickening time at the low temperature and early strength development while still being mixable and pumpable.

Table 3: Material A and Material B Cement Lab Test Results.

Slurry Properties	Material A Slurry	Material B Slurry	Material B Slurry	Non-Thixotropic Slurry#1	Non-Thixotropic Slurry#2
BHST (°F) / BHCT (°F)	80/74	80/74	80/74	70/70	90/90
Density (ppg)	15.8	15.8	13.5	15.8	13.5
PV (cP) / YP (lbf/100ft^2)	75.04/50.3	250.08/52.85	52.23/28.66	149.99/29.88	212.15/33.1
Thickening Time (hh:mm)	01:45	01:21	02:01	02:36	02:01
Time to Reach 50 psi (hh:mm)	04:22	01:53	01:58	04:06	02:47
Time to Reach 100 psi (hh:mm)	05:34	02:20	02:36	04:43	02:51
Time to Reach 500 psi (hh:mm)	11:20	06:10	08:25	09:32	06:46

3.3 Cementing Job Implementation

Prior to the cementing job, Material A and B required different blending procedures as Material A is dry blended and Material B is wet blended and thus Material A needs a longer preparation before use. Beside this there is no other difference in the cementing job execution between pumping the Material A and Material B slurries.

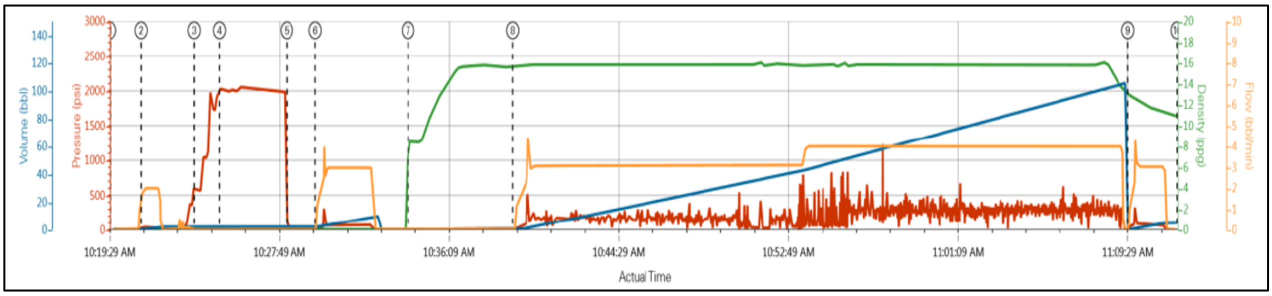

Figure 4: Example of Cement Plug Job Chart with Material A Slurry.

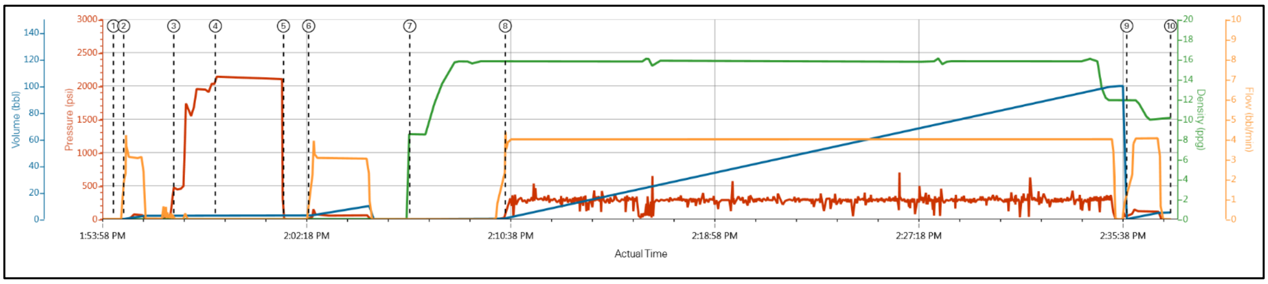

Figure 5: Example of Cement Plug Job Chart with Material B Slurry.

Cementing plug jobs with Material A and Material B were performed through open-ended DP to minimize issues caused by the slurry thickness and unstable hole condition. No issues were found during and after execution of the cementing job.

Table 4: Material A and Material B Slurries Cementing Job Performance Results.

Cementing Job	Success %	Thixotropic Additive
Stabilization Plug#1	41%	Material B
Stabilization Plug#2	39%	Material B
Stabilization Plug#3	138%	Material B
Stabilization Plug#4	44%	Material A
Stabilization Plug#5	47%	Material B
Stabilization Plug#6	0%	Material A
Stabilization Plug#7	132%	Material B
Stabilization Plug#8	25%	Material A
Stabilization Plug#9	18%	Material A

Multiple cement plug jobs were executed to ensure that the hole was stabilized. From these jobs the effectiveness of Material A and B slurries performance were able to be determined and compared by calculating the Success % which is the percentage of the actual height of cement compared to the theoretical height of cement. By comparing the Success % of both slurry types, it was determined that Material B gave better performance than Material A.

4. RESULT

After much effort and the use of low temperature thixotropic cement slurries it was possible to stabilize the hole. Then the surface section was drilled until TD and surface casing was successfully set and cemented.

4.1 Drilling Surface Section stabilize the formation, run surface casing and cement

When the second well, X-2, surface section was originally drilled to planned section TD, total loss of circulation conditions were experienced. Four loss of circulation plugs were pumped in to stop the loss with no success. The surface casing was run with a casing drive system, torque rings, and eccentric float shoe but with the casing seat halfway from the bottom. It was decided to POOH the surface casing and run a clean out BHA.

After the observation of the lack of success of the first four cementing plug during drilling, low temperature thixotropic slurries were used to stabilize the hole during the clean out run. Even though they contained cement, the low temperature thixotropic slurries were not able to stop the losses, but they were able to stabilize the formation. The hole was cleaned out to the bottom. The surface casing was successfully re-run, set and cemented with a stab-in method.

4.2 Continue drilling until planned well TD

Upon successfully overcome the surface hole drilling challenges, drilling was continued until TD with no significant challenges beside a hard formation. The X-2 well are drilled to the planned well TD, ahead of the planned drilling days and under theplanned budget. At the time of writing, well X-2 is still the deepest geothermal well in Indonesia.

5. CONCLUSION

Deployment of low temperature thixotropic cement slurry overcame the surface hole drilling challenges in the X-2 geothermal well. The total loss of circulation zones were not able to be blocked up, but the cement was able to stabilize the unstable Andesitic Boulders that were causing drilling problems and which led to the abandonment of the first well (X-1 well).

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