CASE STUDY

Russia

Multilateral junction stability analysis optimizes design parameters

Advanced geomechanical analysis for complex well geometries enables successful drilling

CHALLENGE

Drill an openhole multilateral junction in weak rock:

- Potential mechanical instability risks
- Minimum mud-weight to maintain junction stability
- Optimum junction design for mechanical stability

SOLUTION

Advanced geomechanical study using numerical simulations to capture the:

- True geometry of junction
- Complex stress field developed around junction
- Dominant failure mechanism and extent of failure zone

RESULT

The outcome of this study provided insight on:

- Optimum junction design
- Minimum mud-weight requirements for junction stability

Overview

For a client in Russia, Halliburton performed a geomechanical study to evaluate the mechanical stability of an openhole, multilateral junction that was planned to be drilled in moderately weak rock. The study incorporated numerical simulations and advanced geomechanical analyses to investigate the feasibility of different junction configurations and to optimize design parameters such as landing depth, junction angle, and well orientation with respect to field stresses. Based on the analysis results, the most stable junction configuration and corresponding minimum mud-weights were determined, and the design parameters were optimized.

Challenge

Drilling of a junction disturbs in-situ stresses and causes high stress concentrations to develop around that junction. The junction can undergo mechanical instability if these elevated stresses exceed the strength of the rock. The stress concentration around the junction depends not only on the field stresses, but also on the geometry of the junction. To maintain the stability of the junction, a minimum internal support, provided by mud weight, is necessary. The conventional wellbore stability analysis workflow, developed based on Kirsch's elastic stress equations, is not applicable for junction stability analysis due to the incompatibility of the problem boundary conditions and geometry with the fundamental assumptions of Kirsch's equations. The conventional method also cannot provide any insights on the post-failure response of the rock in more severe cases, which could range from minor manageable instabilities to total collapse of the junction.

Solution

Numerical simulations were used to incorporate the true geometry of the junction and to evaluate the post-failure response of the rock and the potential extent of the failure zone. Two models, corresponding to two junction angles of 15° and 25°, were built.

For each model, three potential candidate landing zones corresponding to three rock layers (sandstone, claystone, and alevrolit) were evaluated. Elastic stress analysis indicated the development of three distinct stress zones around the junction (**Figure 1**):

- Zone A: Highly stressed zone (compressive zone)
- Zone B: Stress-relaxed zone (potential tension zone)
- Zone C: Slightly stressed zone (compressive zone)

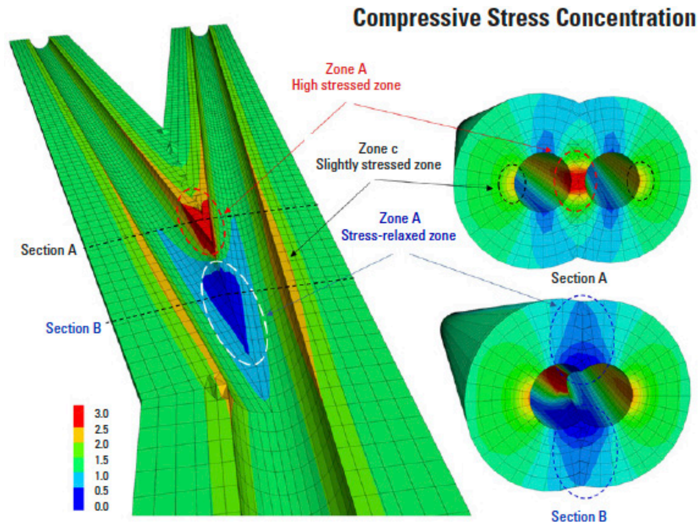

Figure 1: Elastic stress analysis shows three distinct stress zones that have developed around the junction.

The elasto-plastic simulations indicated that Zone A and Zone C were the potential failure initiation zones at the junction, where failure potential depended not only on the rock mechanical properties, but also on the junction angle and field differential stresses. Increasing the junction angle from 15° to 25° reduced the size of Zone B and lowered the compressive stresses in Zone A and Zone C, leading to a more stable junction. Higher initial differential stresses were shown to have a negative effect on junction stability, causing more tension in Zone B and more compressive stresses in Zone A and Zone C. These findings were used to select an optimum base case junction configuration. A post-failure analysis was performed to evaluate the failure progression as a function of mud weight (**Figure 2**).

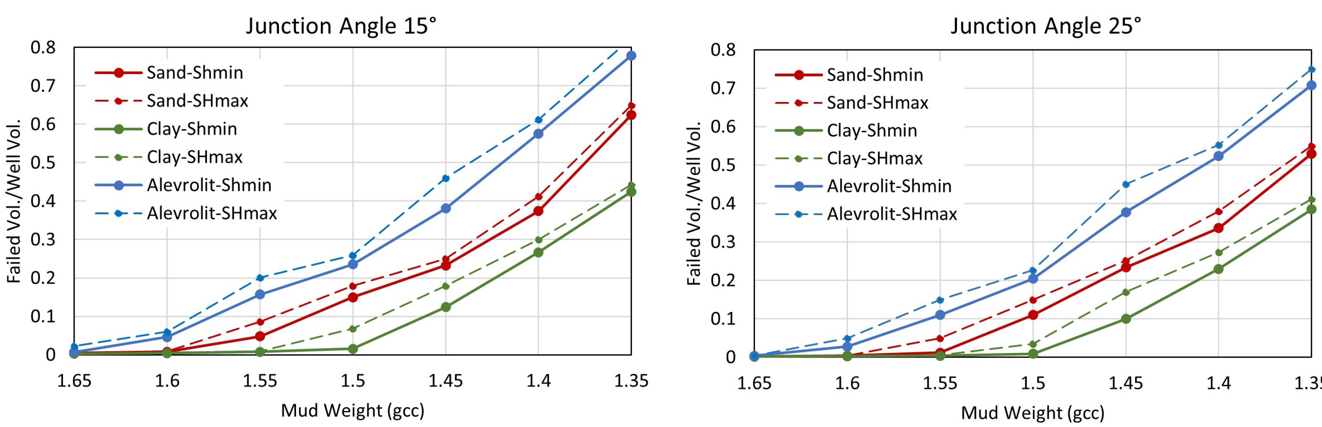

Figure 2: The volume of failed rock increases with a decrease in mud weight, leading to a total collapse of the junction below a critical mud weight.

Results

Based on the failure analysis results, three states were defined, depending on the failure progression around the junction:

- Stable junction – No failure or a minor failure
- Damaged junction – A stable failure (rock failure does not extend far into the rock)
- Unstable junction – A progressive failure, leading to a total junction collapse

The minimum mud weight corresponding to each state was determined for three rock types (**Figure 3**). The feasible configurations were then identified as those with the minimum required mud weight less than the maximum allowable mud weight, defined by the formation fracture gradient (FG), as shown in the table below.

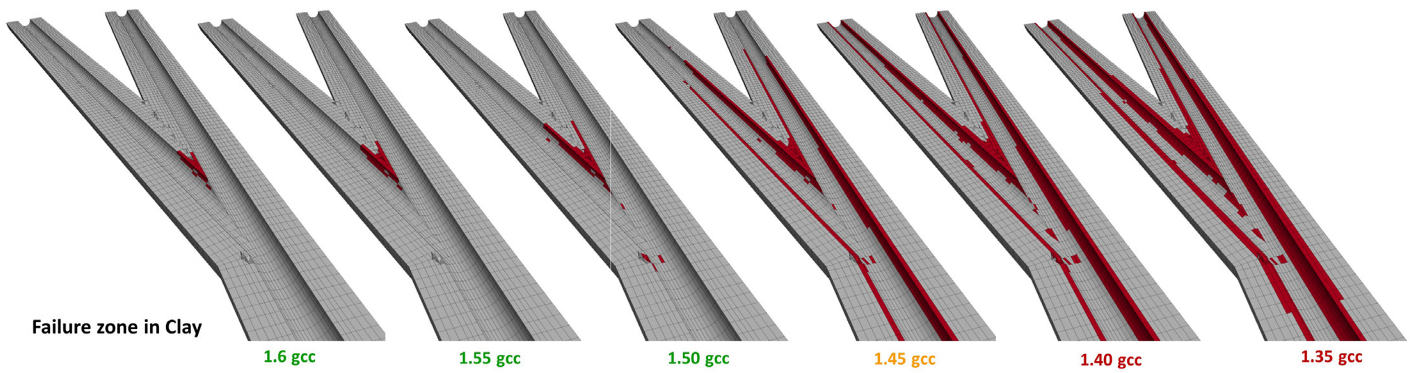

Figure 3: Failed zones around the 15° junction in clay for various mud weights.

LITHOLOGY	FG (GCC)	MUD WEIGHT (GCC)		
		STABLE	DAMAGED (STABLE FAILURE)	COLLAPSE
Clay	1.69	≥ 1.5	1.4–1.5	≤ 1.4
Sand	1.65	≥ 1.55	1.45–1.55	≤ 1.45
Alevrolit	1.55	≥ 1.6	1.5–1.6	≤ 1.5

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