AADE-26-FTCE-013

Innovative Strategies for Mitigating Losses Across Horizontal Reservoir Sections with Self-Degradable Fibers and Acid Soluble Particulates in Qatar

Muhammad Faraz Khan, Zahid Mohammed KARAJAGI, Nader GHOBRIAL and Daniel AHUAR North Oil Company;
Surya Pallapothu, Thein Zaw Phyoe, Jorge Santiapichi, Mohamed Hacene, Eka Yasrul SLB

Copyright 2026, AADE

This paper was prepared for presentation at the 2026 AADE Fluids Technical Conference and Exhibition held at the Marriott Marquis Hotel, Houston, Texas, April 7-8, 2026. This conference is sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers, or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

Lost circulation remains a primary cause of non-productive time (NPT) in drilling operations (de Andrade et al., 2012; Vidick et al., 1988) and presents a significant challenge to cementing integrity (Low et al., 2003). In Qatar, extensive fluid losses are commonly associated with high-permeability formations, naturally occurring or induced fractures, vugular porosity, and cavernous features within limestone reservoirs. The complex geometry and variable aperture of these loss zones are often poorly defined, making effective mitigation difficult (Friedheim et al., 2012).

Drilling through the fractured limestone formations of the Shuaiba and Kharaib reservoirs introduces substantial operational risks, including prolonged NPT and potential formation damage. Traditional lost circulation materials (LCMs), such as particulate, fibrous, and cementitious solutions, have been applied to control losses in fractures up to 5 mm wide. However, these materials can compromise reservoir permeability, leading to reduced well productivity and plugging issues in surface production facilities. To address these challenges, a next-generation LCM is required to effectively seal wider fractures while preserving reservoir performance.

A novel self-degradable fiber-based pill, incorporating acid-soluble particulates, has been engineered to provide a robust sealing mechanism for fractures in the reservoir section. This proprietary formulation establishes a stable, impermeable barrier within fractures, preventing further fluid loss during drilling and completion operations. Unlike conventional LCMs, the fiber matrix degrades naturally over time under in-situ reservoir conditions, thereby minimizing the risk of long-term formation damage. Laboratory evaluations have confirmed the pill's ability to seal fractures up to 12 mm wide while withstanding differential pressures of up to 1,000 psi. Designed for operational flexibility, the formulation can be deployed using multiple pumping techniques, including a dummy bottomhole assembly (BHA), bypass circulation ports, or an open-ended drill pipe.

Field applications in 8½-inch reservoir sections have demonstrated the effectiveness of this self-degradable pill, achieving over 95% reduction in fluid loss. This has enabled continuous drilling operations while preserving reservoir productivity. The pill has been successfully implemented across multiple loss circulation treatments, consistently delivering favorable results across diverse well conditions. A comprehensive field study in Qatar further validated its superior performance in mitigating severe losses within fractured carbonate formations.

Following the development of field-specific treatment protocols over a two-year period, the deployment of this advanced LCM has been systematically expanded across all operators rigs in Qatar. Its consistent success in mitigating severe lost circulation confirms the self-degradable fiber-based pill as a groundbreaking solution for improving operational efficiency and sustaining well performance in fractured limestone reservoirs.

Introduction

A leading operator is executing drilling activities in one of the most geologically complex reservoirs within Block 5 of the Al Shaheen field (Fig. 1). Located in Qatari territorial waters, approximately 80 km north of Ras Laffan, the field comprises 33 platforms and supports over 300 wells. As the largest offshore oil field in Qatar and among the largest globally, Al Shaheen primarily utilizes horizontal drilling techniques to develop four key formations: the Upper Mauddud limestone, Nahr Umr sandstone, Shuaiba limestone, and Kharaib limestone.

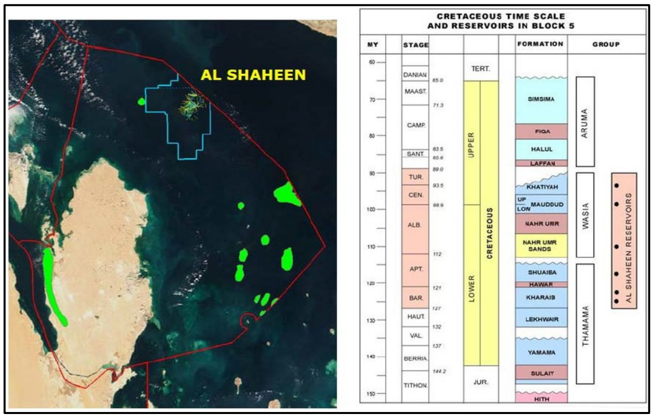
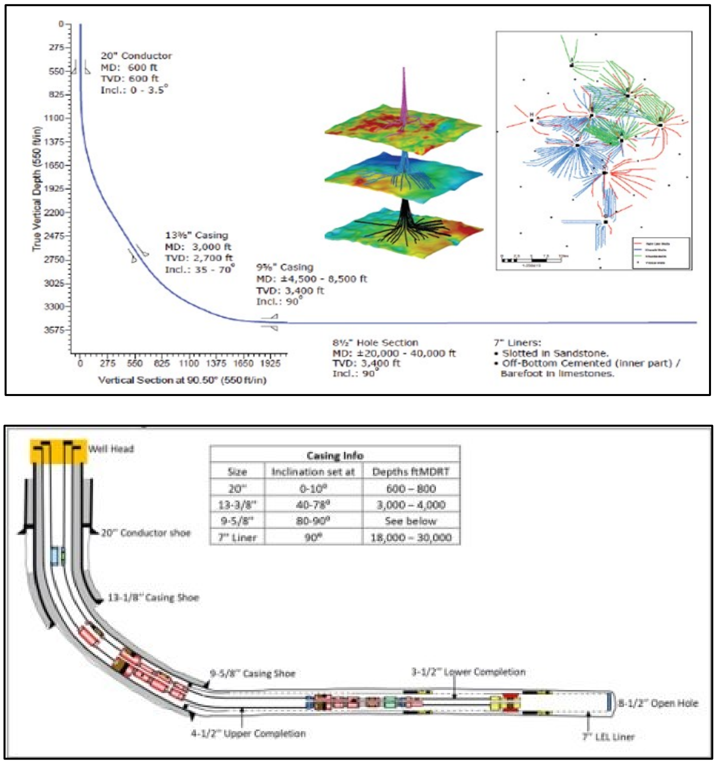


Fig. 1—Left, Al Shaheen field offshore Qatar and right, stratigraphy of Al Shaheen field (Finlay et. al. 2014).

A typical well profile in this field (Fig. 2) begins with a 20-inch conductor pipe (CP) installed using a hammer-driven technique, followed by a 16-inch hole section secured with a 13-⅜-inch casing. This is succeeded by a 12-¼-inch section, where a 9-⅝-inch production casing is set within the reservoir at measured depths (MD) ranging from 4,500 ft to 8,500 ft. The wellbore is built to a 90° inclination, achieving a true vertical depth (TVD) of approximately 3,400 ft. The 8-½-inch reservoir section is drilled horizontally, with measured depths extending between 20,000 ft and 40,000 ft MD. Both production and injection wells are drilled using platform rigs, with well spacing varying from 600 ft in tight carbonate formations to over 5,000 ft in highly permeable sandstone reservoirs. Drilling and cementing operations in carbonate formations face significant challenges due to lost circulation, primarily resulting from natural fractures in the rock matrix. Additionally, unintended hydraulic connections between injection and production wells through these fractures can lead to non-conformance issues, compromising well integrity. Lost circulation in these formations typically ranges from 15 bbl/hr to 300 bbl/hr and can occur during various operations, including drilling, tripping, casing running, and cementing. These fluid losses increase operational costs due to the need for additional materials and may lead to costly delays, such as section abandonment or sidetracking. The deployment of lost circulation materials (LCMs) in horizontal well sections presents further challenges, often limiting their effectiveness in controlling fluid losses.



Casing Info		
Size	Inclination set at	Depths ft MDRT
20"	0-10°	600 – 800
13-3/8"	40-78°	3,000 – 4,000
9-5/8"	80-90°	See below
7" Liner	90°	18,000 – 30,000

Fig. 2—Al Shaheen field well design (Hoch et al. 2010)

The development of lost circulation pills (LCPs) has focused on multi-component formulations that integrate precisely engineered particle size distributions and optimized solids loading. These formulations are designed using advanced analytical techniques that enhance proactive mitigation strategies and improve sealing efficiency, especially in cases where fracture dimensions are not accurately defined by the operator (Ivan et al., 2001). LCP application is determined by the severity of fluid losses, which are categorized as seepage, severe, or total loss. The primary goal of deploying LCPs is to either fully seal the loss zone or substantially reduce fluid loss rates, thereby restoring circulation and maintaining wellbore integrity (Pilehvari and Nyshadham, 2002).

Evolution of Lost Circulation Fluid System

The increasing complexity of well construction in high-loss environments has necessitated innovative lost circulation solutions For fractures extending up to 10 mm in width, conventional LCMs often fail due to the inability of standard particulates to adequately bridge and plug the loss zone if the fracture width is more than 5-mm. To address this challenge, an advanced high-strength, fiber-based lost-circulation system has been developed, incorporating multi-modal fiber networks and high-strength acid-soluble particulates. Sanders et al. (2010) and Friedheim et al. (2012) introduced a high-fluid-loss, high-strength pill system designed to rapidly dehydrate within permeable zones under differential pressure. The resulting seal is sufficiently robust to withstand high differential pressures and mechanical drilling stresses. Clapper et al. (2011) developed specialized testing methodologies to evaluate the performance of these high-fluid-loss fluids.

Mitigating formation damage can also be achieved through the use of removable LCM. Traditional solutions often necessitate post-treatment with acid to dissolve the plug before the reservoir section is put into production. Reported acid-soluble solutions include acid-soluble cement (Bour et al., 1993), acid-soluble particulates (Kang et al., 2012), and acid-soluble gels (Suyan et al., 2009). These materials typically require exposure to 15% HCl or stronger acid solutions, sometimes necessitating HF-HCl mixtures (Lost Circulation Guide, Appendix XI, Page 58) to achieve complete removal. However, acid stimulation treatments pose several challenges, including environmental risks, operational safety concerns, increased costs, and extended operational time. Furthermore, acid penetration depth may be insufficient to fully dissolve the LCS plug, leaving residual impairment in the reservoir section. Additionally, acid stimulation can inadvertently dissolve wellbore walls or create undesired wormholes, compromising well integrity. If lost-circulation materials remain within fractures, they may obstruct stimulation fluids from effectively penetrating the formation, thereby diminishing the efficiency of stimulation treatments.

The first advanced lost circulation pill developed for naturally fractured reservoirs is a fiber-based solution designed to mitigate fluid losses during drilling. This system is capable of sealing fractures up to 5 mm wide, with the primary objective of creating a stable plug that remains intact throughout drilling, retains its integrity until well completion, and subsequently degrades to facilitate hydrocarbon production. A critical challenge in its application is ensuring that the plug forms within the fractures rather than at their entrance. When plugging occurs at the fracture mouth, the material becomes vulnerable to mechanical abrasion from the bottomhole assembly (BHA), increasing the risk of partial dislodgment and compromised sealing effectiveness. Fiber-laden drilling fluids have demonstrated superior fracture-plugging performance. Previous studies (Potapenko et al., 2009) highlight the role of fluid viscosity and velocity in fiber bridging, where fibers accumulate and interlock within the fracture to establish a robust seal. To enhance this mechanism for lost circulation control, a specialized fiber-laden formulation was developed, incorporating well-dispersed fibers and particulates. This optimized system ensures efficient handling, reliable pumping performance, and stability under both surface and downhole conditions. Conventional lost circulation materials (LCMs), while effective at sealing fractures and controlling fluid loss, can have long-term implications on well performance. These materials may reduce formation permeability by creating a residual filter cake that hinders hydrocarbon flow, leading to diminished well productivity. Another factor to consider is that when the well is put into production, the LCP used to seal the fracture may return to the surface and plug the production facility, thereby reducing the production capacity.

For fractured reservoir sections to remove all the risks, the ideal LCP should be self-degrading, eliminating the need for post-treatment. A self-degrading lost-circulation solution facilitates unrestricted reservoir fluid flow into the wellbore and ensures seamless interaction between stimulation fluids and the formation. Advanced degradable fiber-based systems present a promising alternative, offering controlled degradation mechanisms that are activated by specific downhole conditions such as temperature, pH changes, or fluid exposure. These systems provide temporary wellbore integrity while drilling and subsequently degrade to restore full reservoir permeability, ensuring optimal production performance without the risks associated with residual LCMs.

The development of fiber-based drilling fluid systems represents a proactive approach to lost circulation treatment, incorporating engineered fibers and particulates to form a flexible yet stable plug within fractures. Unlike conventional lost circulation materials (LCMs), engineered degradable fibers create a three-dimensional interwoven structure that reinforces the wellbore while reducing fluid loss.

Development of Self Degradable Fiber with acid soluble Particulates

The innovative degradable fiber-based solution was engineered to mitigate fluid losses during drilling operations in naturally fractured reservoirs. Its primary function is to form a stable plug that maintains its integrity throughout the drilling process, persists until well completion, and then degrades to facilitate hydrocarbon recovery. A critical challenge is ensuring the plug forms within the fractures themselves, rather than at the fracture entrances, as the latter is more vulnerable to mechanical wear from the bottomhole assembly (BHA), which may lead to partial displacement of the plugging material. Key attributes of this system include:

- **Fiber-Based Fracture Sealing** – Utilizing degradable fibers to form an interconnected matrix within fractures.
- **Wellbore Strengthening** – Redistributing stress at the fracture tip to mitigate the risk of fracture propagation.
- **High Compatibility** – Suitable for both water-based and oil-based mud (WBM/OBM) systems.
- **Enhanced Pumpability** – Capable of passing through standard drill bit nozzles and downhole restriction
- **Degradable properties –** Fiber can easily degradable based on temperature and pressure at certain period time and it eliminate the risk of surface equipment from plugging.

Fiber-enhanced drilling fluids have demonstrated superior performance in sealing fractures. Studies, such as those by Potapenko et al. (2009), have illustrated the role of fluid viscosity and velocity in fiber bridging, where fibers accumulate and interlock within fractures, forming an effective seal. To optimize this bridging mechanism for lost circulation prevention, a custom-designed fiber-based system was developed, incorporating evenly dispersed fibers and particulates to ensure smooth handling, consistent pumping, and stability in both surface and downhole conditions. During circulation, the high velocity of the fluid through surface pumps, drill string, and bottomhole assembly prevents premature fiber bridging. Once the fluid enters fractures, the velocity significantly drops, allowing the fibers and particulates to accumulate and establish a bridging network that effectively resists fluid loss. This network mitigates losses and restores circulation. The fibers are engineered to degrade in a controlled manner, maintaining the plug's integrity until the well is completed, after which they dissolve to restore permeability and support continuous production. The system's effectiveness has been validated through extensive testing, including laboratory assessments, pilot-scale trials, yard evaluations, and full-scale well implementations. These evaluations focused on ease of mixing and pumping, flow behavior, bridging efficiency, and the stability of the plug under realistic operational conditions, ensuring dependable performance across various drilling scenarios.

The Solution Concept

Drilling through naturally fractured reservoirs presents significant challenges, particularly in managing severe fluid losses. To address this, a novel degradable fiber solution has been engineered to establish a temporary yet robust plug that mitigates fluid loss during drilling, maintains structural integrity until well completion, and subsequently degrades to facilitate production (Fig.3).

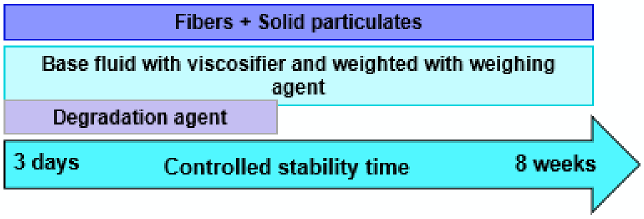


Fig. 3—Example of degradation time.

Key Considerations and Solution Approach

To develop an effective plug, the material selection is critical. The chosen material must be compatible with the downhole environment while exhibiting controlled degradation properties. It should remain stable under drilling conditions and degrade upon exposure to specific well completion triggers.

1. Degradation Mechanism

The degradation process should be activated by well-defined parameters such as temperature, pH, or chemical reactions specific to the well environment. The plug material must degrade in a controlled and predictable manner to ensure seamless well completion.

2. Plug Placement

Fractures in naturally fractured reservoirs vary in size, making accurate plug placement essential. A precise deployment system should be employed to ensure the effective introduction of plug material into fracture openings. Specialized tools or tailored pumping techniques can optimize placement accuracy.

3. Plug Stability

To withstand the abrasive forces encountered during drilling, the plug material may need reinforcement. Incorporating fibers or particulate agents can enhance mechanical stability while preserving the material's degradation characteristics. The reinforcement selection should ensure an optimal balance between durability and controlled degradation.

4. Testing and Validation

Extensive laboratory testing and field trials are required to verify the plug material's effectiveness. Simulated downhole conditions, including variations in pressure, temperature, and fluid composition, should be replicated to assess performance. Field implementation will provide further validation.

The suspension ability of the pill was tested by checking the fluid rheology of the base pill before adding fibers, and stability of the pill was checked by a free fluid test. Furthermore, compatibility of the pill was confirmed using the drilling fluid sample from the field and spacer to be pumped ahead and behind the pill. In case of any need to pump the pill ahead of cement slurry, additional compatibility tests were done between both lead and tail slurries. The pill has also proved to withstand erosion, as observed by Kefi et al. (2010).

Mechanism of Action and Performance

The effectiveness of the degradable fiber solution is influenced by the velocity drop within a fracture as the pill flows from the wellbore. Simultaneously, maintaining high velocity within the pumping line ensures efficient transport through narrow restrictions, such as drill bit nozzles. This controlled flow behavior facilitates proper entry of the degradable fiber solution into fractures, enabling stable plug formation while maintaining favorable pumping properties **(Fig. 4).**

By integrating these considerations, the novel degradable fiber solution offers a viable approach to controlling fluid losses in naturally fractured reservoirs while ensuring an efficient transition from drilling to production. Further research and testing will continue to refine this technology for optimized performance in diverse downhole conditions.

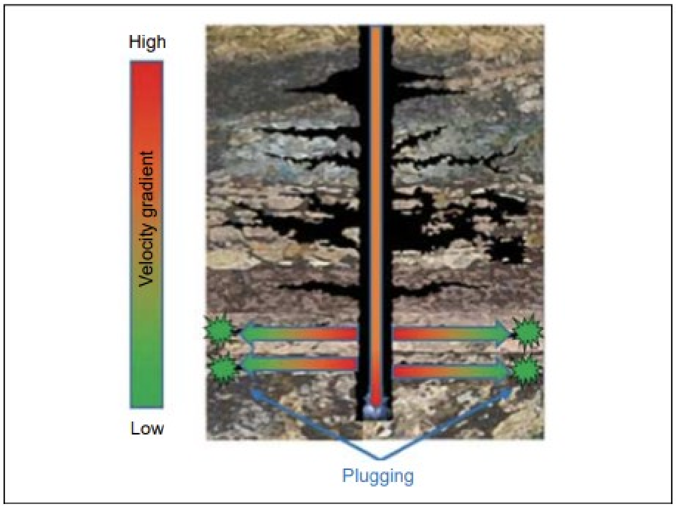


Fig. 4—Velocity profile illustration while pumping fiber system

Experimental Validation

Engineered Degradable Lost Circulation Solution:

The engineered lost circulation solution integrates advanced materials designed to mitigate fluid losses in naturally fractured formations. The core components include:

- **Degradable Fibers**: Engineered to provide controlled degradation properties, these fibers optimize plugging efficiency while enhancing mechanical stability. Their degradation can be triggered by specific downhole conditions, ensuring complete removal when required.
- **Viscosifier**: A critical component that ensures uniform suspension and distribution of engineered fibers and solids within the base fluid. Proper dispersion of these materials is essential for forming an effective and homogenous pill system, optimizing performance under various downhole conditions.
- **Solid Package (Coarse Particles)**: Strategically selected coarse particles enhance the robustness of the plug, improving sealing efficiency and ensuring mechanical resilience under varying wellbore conditions. These particles contribute to forming a stable and durable plug within fracture networks.
- **Agglomerate High-Performance Particulate**: This acid-soluble, high-strength particulate is designed to reinforce the fiber network, improving overall plugging efficiency under severe loss conditions. Its solubility in acid ensures effortless removal post-drilling, facilitating seamless production initiation.

Apparatus Set-Up:

Fibers provide an innovative approach to addressing the challenge of loss-zone characterization. Kefi et al. (2010) introduced a composite blend specifically designed to manage lost circulation in fractured formations. Their methodology involves four critical steps:

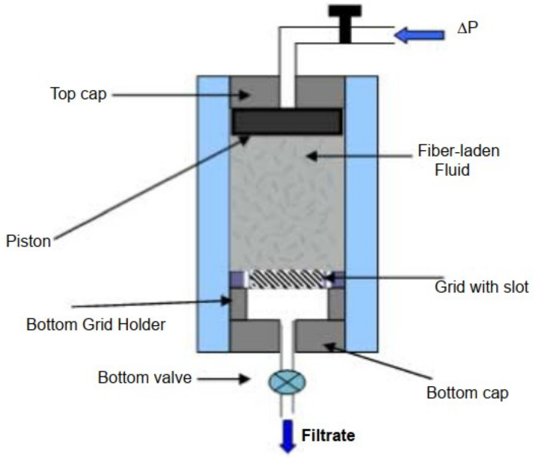
1. **Dispersing a Composite Lost Circulation Material (LCM) into a Base Fluid**: Ensuring homogeneous distribution of LCM to facilitate effective sealing.
2. **Creating a Fiber Network**: The engineered fibers form a structural bridge at the entrance of fractures, mitigating fluid loss.
3. **Sealing the Fiber Network with Particulate Materials**: The introduction of particulate matter enhances the mechanical integrity of the fiber network, reinforcing the seal.
4. **Maintaining Seal Integrity**: The composite blend is engineered to sustain plugging efficiency under downhole conditions.

This approach utilizes a meticulously engineered combination of granules with varied particle sizes alongside rigid and flexible fibers, optimizing plugging performance.

To evaluate the effectiveness of spacer fibers in plugging, a modified fluid loss cell setup was developed for routine testing. A compact and user-friendly test system was designed to assess the plugging efficiency of fiber-laden fluids (Fig. 5).

This setup comprises a metal tube filled with a precisely formulated slurry containing fluid, fibers, and particles. The slurry is then forced through a 10-mm slot to simulate a fracture environment. The test formulation is introduced into the tube, and a piston is inserted to isolate the test fluid from the pressurizing water. A pump maintains a constant flow rate, accurately replicating downhole fracture velocities. Throughout the experiment, real-time pressure monitoring ensures precise performance evaluation (Nicolas et al. 2014).

By integrating these specialized materials and methodologies, the engineered degradable lost circulation solution delivers an advanced, adaptable, and efficient approach for mitigating severe fluid losses (up to 10-mm) fracture width in complex drilling environments **(Table -1).**



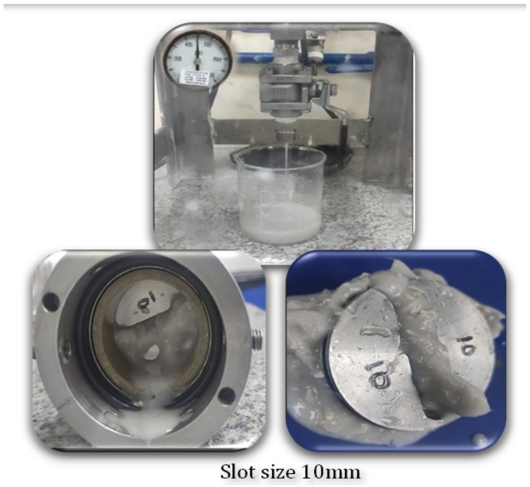


Fig. 5—Modified fluid loss cell used to simulate plugging test

Pill Density		9.4 ppg
Plugging Test Results		
Grid Geometry & Test Temperature	Result	Grid Geometry & Test Temperature
10mm slot @ 27° C [80°F]	Plugged	10mm slot @ 27° C [80°F]

Table 1 – Plugging efficiency test results.

Plugging mechanism:

The effectiveness of the fiber-laden pill in bridging and sealing fractures is strongly influenced by the velocity of the fluid and its rheological behavior. The interaction between fluid velocity and fiber bridging properties is dictated by the competition between dragging forces and frictional resistance within the fracture. The primary factors influencing this mechanism include:

- **Velocity Influence**: As fluid velocity increases, the ability of fibers to bridge fractures diminishes due to higher dragging forces. To compensate, a higher fiber concentration is required to initiate and sustain bridging.
- **Shear and Viscosity Effects**: The fluid's viscosity profile under shear conditions plays a key role in maintaining fiber dispersion and optimizing plugging efficiency.

When tested, three distinct behaviors are observed, characterized by specific pressure profiles (Fig. 6):

- **No Bridging**: The fluid and solid components freely discharge through the slot with minimal or no pressure buildup, indicating the absence of plugging.
- **Bridging Without Plugging**: No solids exit the slot, but fluid continues to permeate through the fiber structure. As pressure gradually increases, additional fibers accumulate, leading to a progressive reduction in permeability.
- **Complete Plugging**: A rapid reduction in flow is observed as system pressure increases. The setup reaches its pressure limit, preventing further fluid or solids from exiting the slot, indicating a successful seal.

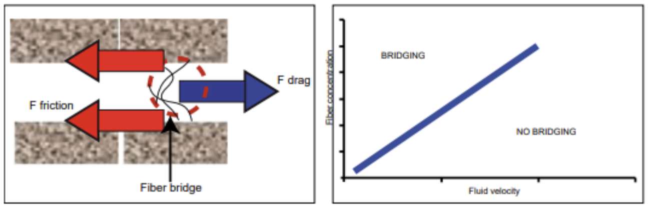


Fig. 6—Typical plugging mechanism

Plug Stability Properties

A key feature of this novel solution is the controlled degradability of the plug. Initially, the plug is formed to mitigate lost circulation, ensuring wellbore stability throughout drilling and completion operations. The plug remains intact during critical activities such as drilling to total depth, logging, coring, casing installation, cementing, perforation, and completion hardware placement. Once the well is ready for production, the plug must degrade to restore permeability and enable hydrocarbon flow through the fractures.

The degradation rate of the fibers was investigated through screening tests, where fiber weight loss over time was assessed in controlled-temperature ovens. A range of additives was used to regulate pH and achieve tailored degradation times spanning from a few days to several weeks across a temperature range of 40°C to 85°C (104°F to 185°F). Research is ongoing to extend application temperatures beyond 85°C (185°F).

To establish a correlation between fiber degradation and plug stability, a specialized experiment was conducted. A plug was first formed inside a metal tube connected to a pump and placed within an oven. A continuous flow of reservoir-analog fluid was applied under high pressure, and pressure responses were monitored over time. A sudden pressure drop indicated the initiation of plug cleanup, with permeability measurements confirming a rapid transition to fluid flow. Fig. 7 illustrates an example of system stability time determination.

By integrating these specialized materials and methodologies, the engineered lost circulation solution delivers an advanced, adaptable, and efficient approach for mitigating severe fluid losses in complex drilling environments.

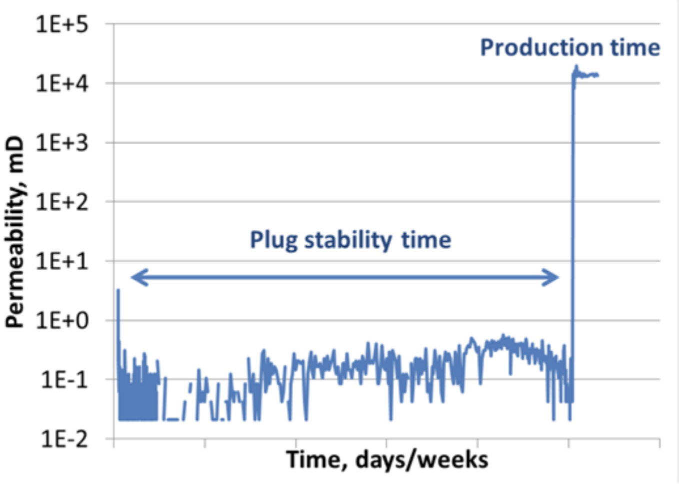


Fig. 7— **System stability time determination**

Yard Trials and Field Verification

Yard trials were conducted to validate the mixing and pumping performance of the formulated fluid under field conditions using actual bottomhole assemblies.

A full-scale mixing setup was established, incorporating a batch mixer and a high-pressure pumping unit. The test configuration included a bottomhole tool on the high-pressure line, with a drill bit featuring adjustable nozzle sizes (Fig. 8) at the end of the line. This setup allowed for realistic evaluation of fluid behavior during pumping, ensuring that the fiber-laden slurry could be effectively mixed, transported, and deployed in conditions simulating downhole environments.

By integrating these specialized materials and methodologies, the engineered lost circulation solution delivers an advanced, adaptable, and efficient approach for mitigating severe fluid losses in complex drilling environments.

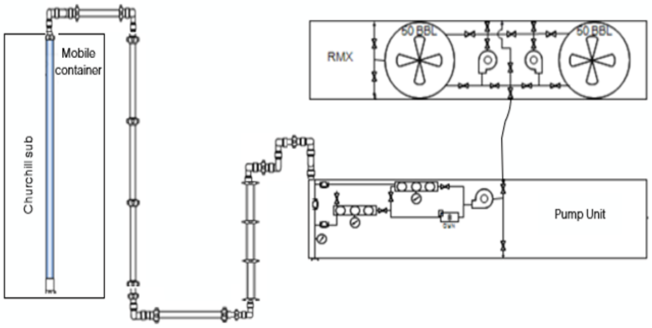


Figure 8: Yard Trial Setup

A series of tests were performed using this setup to investigate seven different parameters, as described in Table 2. These tests aimed to assess the impact of various operational conditions on fluid performance, plugging efficiency, and degradation behavior. The controlled environment enabled systematic evaluation and optimization of the engineered lost circulation solution.

By integrating these specialized materials and methodologies, the engineered lost circulation solution delivers an advanced, adaptable, and efficient approach for mitigating severe fluid losses in complex drilling environments.

Parameters	Condition Tested	Result
1	Mixability condition with formulation in the batch mixer	Passed
2	Homogeneity after mixing the formulation (no sign of segregation)	Passed
3	Flowability condition	Passed
4	Compatibility with Downhole tools (nozzles 1-in port) (no sign of plugging)	Passed
5	Pumping rate test (0.5 to 3 BPM)	Passed
6	Pumping rate less than 0.5 BPM (sign of plugging)	Not Passed

Table 2: Conditions Tested During Yard Trials

Observations and Analysis

A series of structured tests were conducted to evaluate the performance of the engineered lost circulation solution under field conditions. These trials aimed to ensure the formulated fluid could be effectively mixed, maintained in a homogenous state, and pumped through downhole tools without causing operational issues. The parameters assessed during these trials are outlined in above Table 1.

- Mixability and Homogeneity: The engineered fluid exhibited excellent mixability within the batch mixer, maintaining uniform dispersion without visible segregation of fibers or particulates.
- Flowability Performance: The formulated slurry demonstrated smooth flow characteristics, ensuring effective transport through the system.
- Compatibility with Downhole Tools: The solution successfully passed through downhole nozzles without obstruction, confirming its adaptability to bottomhole assemblies.
- Pumping Rate Performance: The fluid was effectively pumped at rates between 0.5 and 3 BPM, maintaining stability and avoiding plugging. However, at rates below 0.5 BPM, partial plugging was observed, suggesting the need for an optimized pumping protocol when operating at lower flow rates.

These trials confirmed the robustness of the engineered lost circulation solution in real-world mixing and pumping conditions while identifying flow rate thresholds for optimal performance. Further testing and formulation adjustments may be required to enhance low-rate pumpability and mitigate plugging tendencies.

Recommended placement procedure

Effective placement of lost circulation material (LCM) is critical for mitigating fluid losses during drilling operations (Muhammad, F.K. et al. (2021)). The placement strategy depends on the type of drill string configuration and whether returns are observed at the surface. The following guidelines outline the recommended procedures for Open-Ended Drill Pipe (OEDP) and Bottom Hole Assembly (BHA) with Bypass Sub, categorized by returns and no returns (total losses)

The placement mechanism of the Pill is optimized based on conventional LCM pill pumping techniques. The decision to deploy the Composite Mat Pill depends on the loss rate observed upon reaching the loss zone.

- **Step 1:** Upon encountering the loss zone during drilling, halt drilling operations and determine the loss rate (static/dynamic) by adjusting the pumping rate up to 550 GPM (Fig. 9).

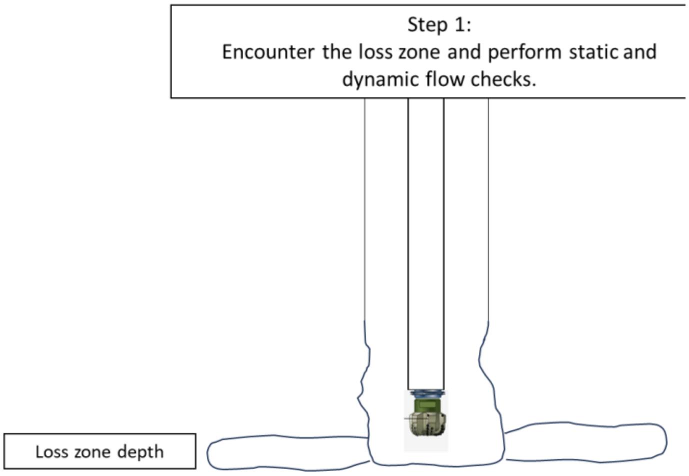


Fig. 9—Step 1: Hitting loss zone.

- **Step 2:** Once the loss rate is confirmed at the loss zone depth, drill at least an additional 100 ft to fully assess the loss zone. Then, re-evaluate the loss rate within a range of 100 GPM to 550 GPM (Fig. 10).

If the loss rate is <50 BPH at 550 GPM, continue drilling.

If the loss rate is >50 BPH at 100 GPM (or >120 GPM at 550 GPM), deploy the engineered Composite Mat Pill.

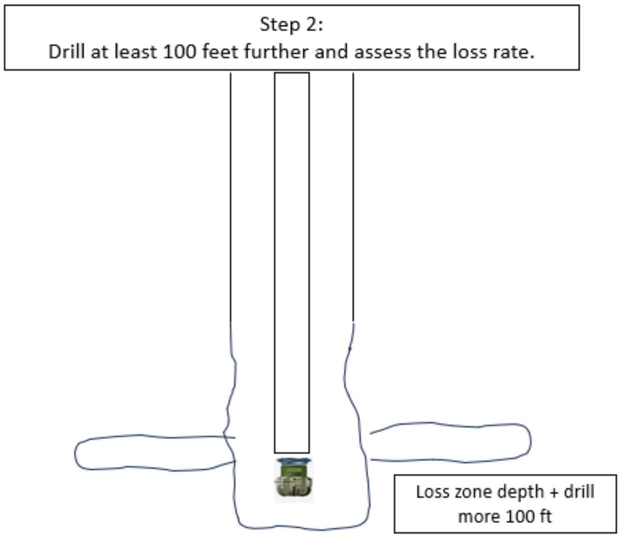


Fig. 10—Step 2: Access the loss rate.

- Step 3: Once the loss rate is confirmed and the decision is made to spot the pill, position the bit 10 ft above the loss zone (with the circulating sub positioned approximately ±190 ft above the loss zone). Activate and confirm the circulating sub is open before proceeding with the Composite Mat Pill placement using the following pumping techniques (Fig. 11):
    - Pump the pill at the maximum allowable rate, ensuring continuous pumping without interruptions.
    - Do not pump fresh or seawater ahead of or behind the engineered Composite Mat Pill.
    - Displace the Composite Mat Pill out of the circulating sub by pumping:
        - Surface line volume
        - String volume up to ports
        - BHA/open hole annulus
        - An additional 1 bbl of drilling fluid
    - Rotate the string occasionally at 5–10 RPM to aid placement.
    - Close the annular and choke "on the fly" before the Composite Mat Pill exits the circulating sub.
    - Ensure the entire Composite Mat Pill is fully displaced from the string.
    - Adjust the pump rate as required, depending on Maximum Allowable Surface Pressure (MASP).

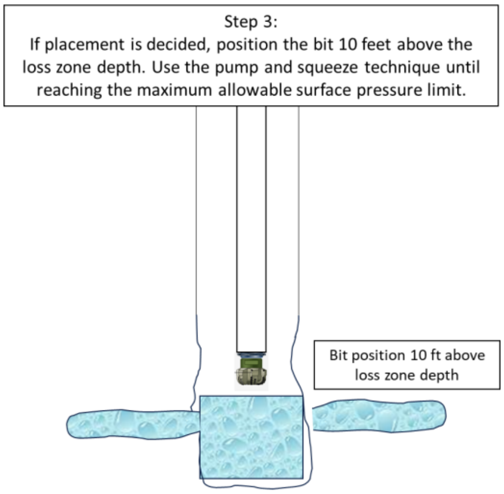


Fig. 11—Step 3: Placement technique

- **Step 4:** After successfully spotting the pill, **pull out of hole (POOH) for 5 stands** and allow the pill to **soak for 60 minutes**. Following the soaking period, evaluate the **dynamic loss rate** across a flow rate range of **100 to 550 gpm**. Once the initial check is complete, **run back in hole (RIH) to the drilled depth** and reassess the loss rate (Fig. 12):
    - **If the loss rate is <50 bph at 550 gpm**, continue drilling.
    - **If the loss rate is >50 bph at 100 gpm** (or **>120 gpm at 550 gpm**), spot another **engineered Composite Mat Pill** and repeat the process.

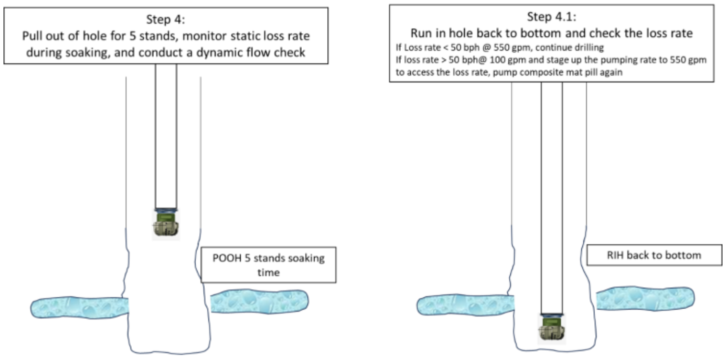


Fig. 12—Step 4: Post placement technique

Field Case Studies

The formulation was pumped in the actual job with real-case lost circulation events. The conditions are detailed in Table 1. The jobs were performed successfully where the losses were expected.

Condition	**Field Case 1**	**Field Case 2**
Formation Type	Reservoir section, production zone	Reservoir section, production zone
Deviation	Horizontal	Horizontal
BHA configuration	Directional with mud motor and circulation sub	Directional with mud motor and circulation sub
Depth (MD)	8,042 ft	8383 ft
Temperature (BHST)	140° F. (60° C)	140° F. (60° C)
Initial Losses	Dynamic Losses (230 bbl/hr [35 m3/hr])	Dynamic Losses (>550 bbl/hr[85m3/hr])
Mud Density	9.2 lbm/gal	9.2 lbm/gal

Table 1. Field Case Studies

The following is general procedure used to spot a pill:

1. Prepare the pill in advance before start drilling 8-1/2" OH
2. Identify the type of losses and estimate location of loss one
3. Once the losses zone is identified, open the circulation sub, performed dynamic check
4. Pump the pill through circulation sub with drill bit 2 stands above the loss zone
5. When the pill is displaced, start squeezing once the pill reach the circulation port to make sure the pill doesn't go up
6. Soaking for a hour
7. Perform dynamic check across the loss zone

Field Case Studies 1:

The 8 1/2-in. openhole section was drilled from 9 -5/8" casing shoe to 8042 ft Dynamic loss rate (230 bbl/hr. [35 m3/hr.]) was observed with 13 bbl/min [2066 lpm]. After observing the losses, client decided to pump 70 bbls (11 m3) from above. The formulation was prepared in rig mud pitt with recirculating centrifugal pump. A cementing pump unit with two Triplex pumps was used to pump the formulation down hole. The pill was pumped at 2.5 bbl/min [400 L/min]. Pump pressure was below 460 psi [32 bar], and no pressure increase was recorded when the pill passed through the circulation sub.

After the pill was spotted, it was soaking for an hour, dynamic flow check was performed with 550 gpm with no losses. Continued drilling to TD without additional losses.

Field Case Studies 2:

The 8 1/2-in. open hole section was drilled from 9 -5/8” casing shoe to 8,383 ft. Dynamic loss rate (>550 bbl/hr[85 m3/hr.])was observed with 13 bbl/min [2066 lpm] . After observing the losses, client decided to pump 70 bbls (11.1 m3) from above. The formulation was prepared in rig mud pitt with recirculating centrifugal pump. A cementing pump unit with two Triplex pumps was used to pump the formulation down hole. The pill was pumped at 2.5 bbl/min [400 L/min]. Pump pressure was below 730 psi [50 bar],

After the pill was spotted, it was soaking for an hour, dynamic flow check was performed with 550 gpm with 50 bbl/hr (7.9 m3/hr). Continued drilling to TD without additional losses.

In both cases, the **pumping pressure at the top of the loss zone** increased from **150 psi to 300 psi**, demonstrating a significant improvement in **loss rate control and pressure response** with both pill application.

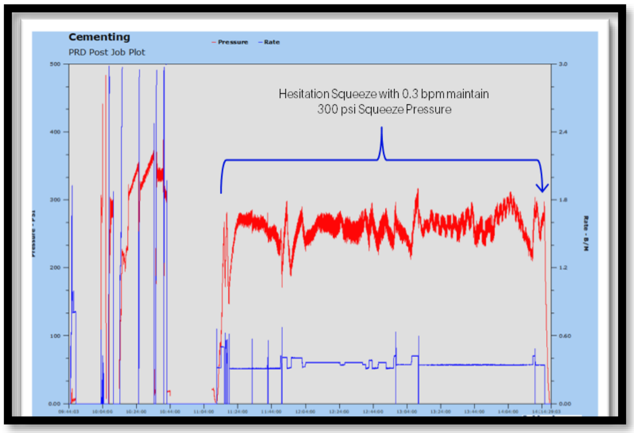


Fig. 13—Post Job Plot during squeezing LCM

A similar approach has been successfully implemented to mitigate losses across multiple sections, as illustrated in **Fig. 13**. Depending on operational requirements at the time of losses, the pills were deployed using either an **open-ended drill pipe (OEDP) or circulation subs**. All treated wells were subsequently cemented without encountering significant losses.

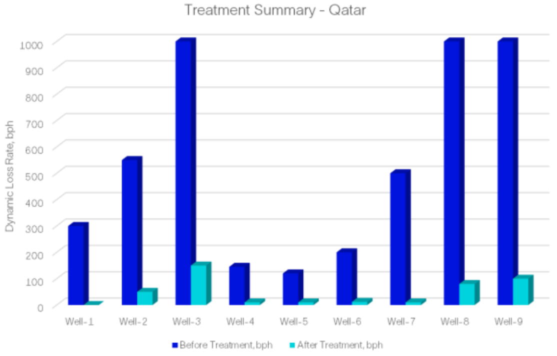


Fig. 14—Treatment Summary

Conclusions:

Field trials have validated the effectiveness of the degradable fiber pill across multiple performance parameters, including mixing and pumping efficiency, flow behavior, plugging performance, plug stability, and reservoir compatibility. This advanced lost circulation solution integrates degradable fibers and solids, offering the following key advantages:

- Water-based formulation mixed with engineered fibers and particulate materials directly in the mud pit.
- Optimized viscosity to ensure efficient transport and suspension of solids.
- Seamless pumping through a 1-inch circulation port without plugging.
- Velocity reduction within fractures, facilitating effective bridging and plugging, making it suitable for sealing fractures up to 10 mm wide.
- Controlled self-degradation, ensuring minimal formation damage and enabling fractures to function as production pathways.
- Adjustable stability duration, ranging from several days to multiple weeks, with operability at temperatures up to 175°F.

The system has been extensively tested in laboratory settings, large-scale yard trials, and field applications, yielding the following key observations:

- Straightforward mixing and pumping using standard surface equipment.
- Full compatibility with downhole tools, including mud motors and drill bits.
- Effective sealing of severe losses, with negligible residual losses post-treatment.
- Predictable degradation and cleanup during production, with no negative impact on well productivity.

Acknowledgments

The authors gratefully acknowledge the management of North Oil Company for their support and permission to publish these results.

Nomenclature

m^3/h = Metric cube per hour
kg/m^3 = Kilogram per metric cube
in^2 = Inch Square
MD = Measure Depth
TVD = Total Vertical Depth
bbl/hr = barrel per hour (bph)
ft = feet
in = inch (’’)
µm = micron
gpm = gallons per minute

ppg = pound per gallon
°C = Degree Celsius
°F = Degree Fahrenheit
BHST = Bottom Hole Static Temperature
bbl = barrel
psi = pound per square inch
rpm = Rotations per minute
MASP = Maximum Allowable Surface Pressure
LCM = Lost Circulation Material

References

Muhammad, F.K. et al. (2021) ‘Engineered reinforced composite mat pills to effectively combat losses while drilling in Qatar’, Day 1 Tue, June 08, 2021 [Preprint]. doi:10.2118/201030-ms.

Droger, Nicolas, Eliseeva, Ksenia , Todd, Larry , Ellis, Chelsea , Salih, Omer , Silko, Nikita , Fu, Dan , Meyer, Arnoud , and Raul Bermudez. "Degradable Fiber Pill for Lost Circulation in Fractured Reservoir Sections." Paper presented at the IADC/SPE Drilling Conference and Exhibition, Fort Worth, Texas, USA, March 2014.

De Andrade, Alexandre Victor, Diaz, Lenin Omar, Bermudez, Raul , Bedino, Henry Daniel, Carrillo, Nixklafe Neil, Vargas, Candelario Delgado, Carrillo, Angel Pedro, and Ignacio Ramirez Martinez. "Fiber Technology Simply and Effectively Cures Total Losses in Southern Mexico Without Knowing Size of Fractures." Paper presented at the SPE Latin America and Caribbean Petroleum Engineering Conference, Mexico City, Mexico, April 2012.

Fidan, E., Babadagli, T., and E. Kuru. "Use of Cement as Lost-Circulation Material: Best Practices." Paper presented at the Canadian International Petroleum Conference, Calgary, Alberta, June 2004.

Potapenko, D. I., Tinkham, S. K., Lecerf, B., Fredd, C. N., Samuelson, M. L., Gillard, M. R., Le Calvez, J. H., and J. L. Daniels. "Barnett Shale Refracture Stimulations Using a Novel Diversion Technique." Paper presented at the SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, January 2009.

Pilehvari, Ali A., and Venkata R. Nyshadham. "Effect of Material Type and Size Distribution on Performance of Loss/Seepage Control Material." Paper presented at the International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana, February 2002.

Friedheim, James E., Sanders, Mark W., Arias-Prada, Jorge , and Ryan P. Shursen. "Innovative Fiber Solution for Wellbore Strengthening." Paper presented at the IADC/SPE Drilling Conference and Exhibition, San Diego, California, USA, March 2012.

Vidick, B., Yearwood, J. A., and H. Perthuis. "How to Solve Lost Circulation Problems." Paper presented at the International Meeting on Petroleum Engineering, Tianjin, China, November 1988.

Loeppke, G.E., Glowka, D.A. and Wright, E.K., 1990. Design and evaluation of lost-circulation materials for severe environments. Journal of Petroleum Technology, 42(03), pp.328-337.

Low, Nick, Daccord, Gerard, and Jean-Philippe Bedel. "Designing Fibered Cement Slurries for Lost Circulation Applications: Case Histories." Paper presented at the SPE Annual Technical Conference and Exhibition, Denver, Colorado, October 2003.

Kefi, Slaheddine , Lee, Jesse C., Shindgikar, Nikhil Dilip, Brunet-Cambus, Chrystel , Vidick, Benoit , and Nelson Ivan Diaz. "Optimizing in Four Steps Composite Lost-Circulation Pills Without Knowing Loss Zone Width." Paper presented at the IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Ho Chi Minh City, Vietnam, November 2010.