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Optimization of Squeeze Cementing Using Ultrafine Cement in Tight Talang Akar Formation, Ramba Field

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ABSTRACT

Ramba Field, Pertamina Hulu Rokan Zone 4 is located in South Sumatera, Indonesia. There are secondary cementing problems due to the tight injectivity rate. The failure caused a loss of time and a loss of production opportunity. This paper aims to demonstrate the successful application of ultrafine cement in rejuvenating a brownfield site in South Sumatera by effectively shutting off water channels.

The approach involved a thorough reservoir analysis to identify water- producing zones and optimize well placement. Ultrafine cement was then precisely placed using advanced cementing techniques, targeting water channels and permeable zones. Reservoir characteristics in the Talang Akar Formation have a good permeability and a normal injectivity rate, but when using conventional slurry, it was difficult to inject into the reservoir. Ultrafine cement material has a smaller particle size than conventional cement, which gives it the penetration ability to seal thief channel behind the casing and even the pore throat.

The application of ultrafine cement led to a substantial reduction in water production, resulting in improved well productivity and enhanced sustainability of reservoir operations. The cement bond data result showed improved amplitude that could not be achieved by conventional Class G oil well cement and brought effect to decreasing water cut result. Ultrafine Cement with finer grain material (3-5 micron)/1000 Mesh compared to normal API Class G Cement around 325 Mesh resulting Low permeability slurry and rapid compressive strength that able to penetrate tiny channel behind casing. It was effective to improve cement bond in microchannel and restrict fluid flow in unwanted zone resulting Good CBL (<10 mV). This method can keep the production up to true reservoir production performance while minimizing water management issues and repetitive squeeze cement job and reduce rig cost.

This paper contributes novel insights by showcasing the successful utilization of ultrafine cement for water shut-off in brownfield rejuvenation efforts. By emphasizing the link between effective water management and sustainable well production, it adds valuable knowledge to the petroleum industry's quest for environmentally conscious and economically viable reservoir management practices that are applicable to tight reservoirs around the world.

Keywords: rejuvenation; brown field; production decline; increasing water cut; chanelling; secondary cement; ultrafine cement; water shut-off optimization

I. INTRODUCTION

The Ramba Field in South Sumatera, Indonesia, faces significant challenges in managing water production due to water channeling and coning issues. One of the critical issues encountered, especially in the Talang Akar Formation (TAF) at Ramba Field, characterized by fluvio-deltaic sediments, is a mature reservoir where water breakthrough and poor cement bonding have leads to increased water cut and subsequent reduction in hydrocarbon production. Traditional cementing methods using standard oil cement class G often fall short in effectively sealing these tight formations, particularly when the cement fails to penetrate the formation's pore spaces, resulting in poor zonal isolation.

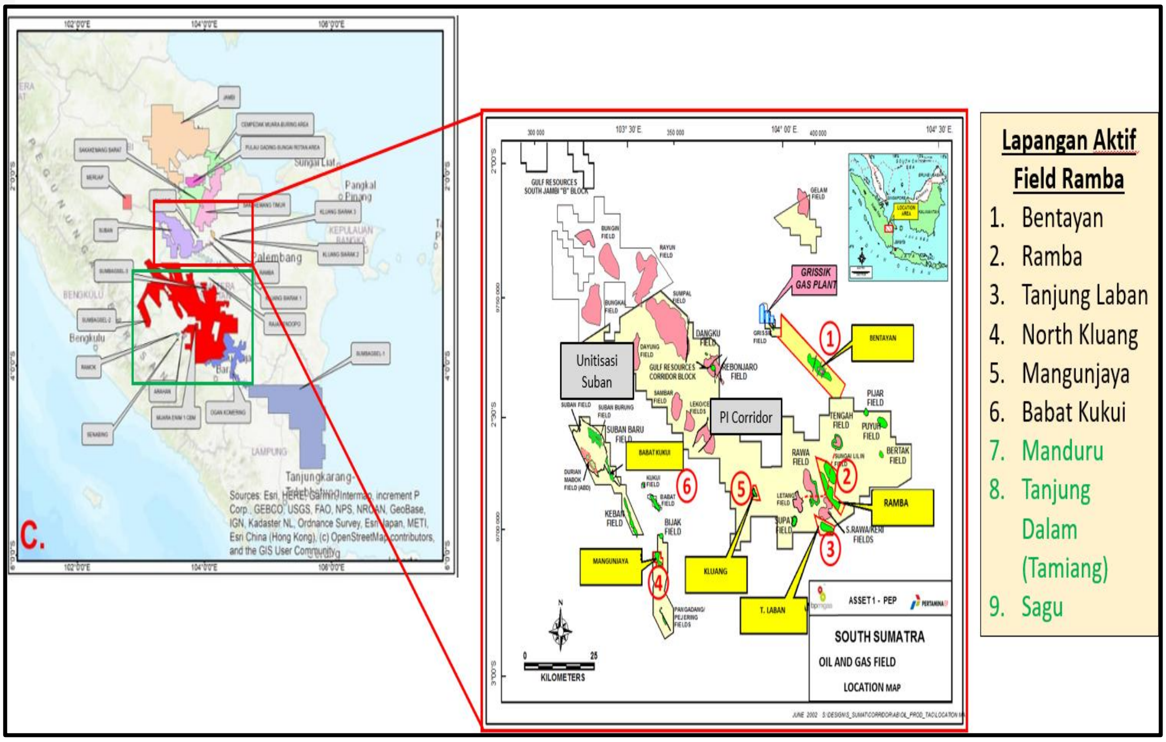

Figure 1. Site Location Ramba Field

Ramba Field is one of the oil and gas producing fields in the PT Pertamina EP Regional 1 Zone 4 area. In 2023, the average oil production was 5037 BOPD and gas production was 12 MMSCFD. Referring to the analysis of production performance data in the Ramba field using the OFM production database and the 2023 Low and Off production report, there was a decrease in production in the Ramba field.

Based on historical production data, the annual decline rate of the Ramba field is quite high, which is 15%/year. The results of the low and off data recapitulation, the dominant causes of production decline in terms of subsurface are increasing water content, decreasing reservoir pressure, scale problems and sand problems. The increase in water content contributed around 57.6% of the total low and off. The causative factors are water breakthrough from injection wells, having a strong water drive reservoir, well integrity problems in production wells and suboptimal water shut off work because currently remedial cementing is still using Class G cement, where it is very difficult to inject slurry cement into the reservoir.

The Bentayan Structure began production in 1986 with a rate of 1674 BLPD / 1644 BOPD / WC 2%, Cumulative oil production to date is 32 MMstb (status 2023) with RF 18% (2P). The total number of wells that have been drilled is 134 wells, with the number of active production wells 54 wells, 19 active injection wells, 49 suspended wells and the status of other wells 6 P&A wells. The TAF C layer is a layer in the Bentayan Structure that contributes the most cumulative production of 21140 MSTB with a Recovery Factor (RF) of 24.4%. In terms of RF, Layer C still has the potential to be developed considering the ultimate recovery calculated based on SCAL data of 39.7% so that there is still a remaining reserve of 13203 MSTB. The RTA-01 and SNA-01 wells are new wells that have not reached the target due to well integrity problems.

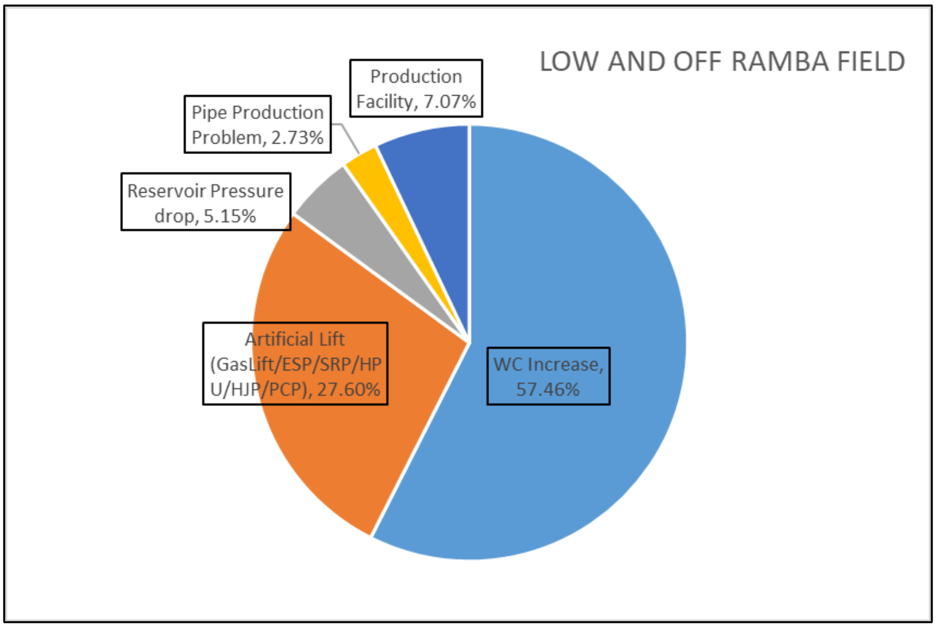

Figure 2. Low and Off Ramba Field

From the Piechart above, shows that the dominant cause of the production decline that occurred in the Ramba Field was the increase in water content with a production loss of 9,899 barrels of oil or 57.46% of the total Low and Off. In terms of economic calculations, the potential loss for the company is USD 791,920 or around Rp 158,384,000, - so an accurate analysis is needed to increase the success of the water shut off work in the Ramba field.

The stages carried out are the creation of IPR well graphs, decline rate analysis, and correlation of Open Hole (OH) logs with surrounding wells to determine the potential of the layer, Chan Diagnostic Plot analysis to determine the cause of the increase in water content due to water coning or water channeling, CBL data analysis to determine the compressive strength and bond index values, VDL data analysis to determine the density of cement behind the casing, mechanical water shut off with ultrafine cement at tight formation intervals that experience water channeling, reperforation of existing production layers, evaluation of water shut off results by conducting positive tests and conducting quantitative and qualitative analysis through CBL-VDL logs and conducting production observations to confirm the results of the ultrafine cement.

This thesis aims to address the significant production challenges faced by wells RTA-01 and SNA-01 in the Ramba Field, primarily due to high water cut and compromised well integrity. The primary objective is to identify the root causes of the increased water cut in these wells, which involves analyzing factors such as formation water influx, water channeling pathways, and the effectiveness of previous cementing treatments.

Additionally, the study seeks to evaluate the adequacy of the conventional oil cement class G used in these wells, determining whether it is sufficient for the tight formation conditions or if alternative materials are necessary. A key goal is to determine the most effective water shut-off method for mitigating water channeling issues, which includes designing remedial cementing techniques that utilize ultrafine cement to effectively seal channels and improve zonal isolation. The Ultrafine cement system is designed for use in thief zones, water and gas zones, casing leaks, microannuli, and to seal gravel packs. The fine particle size allows penetration through very small casing fractures and/or finely packed sands without the need for large amounts of fluid loss additives. Ultrafine is also used to seal small casing leaks where conventional Portland cement (Class G) is unsuccessful due to the coarse particle size. The Ultrafine cement system develops rapid compressive strength, producing a durable and long-lasting cement casing in harsh environments.

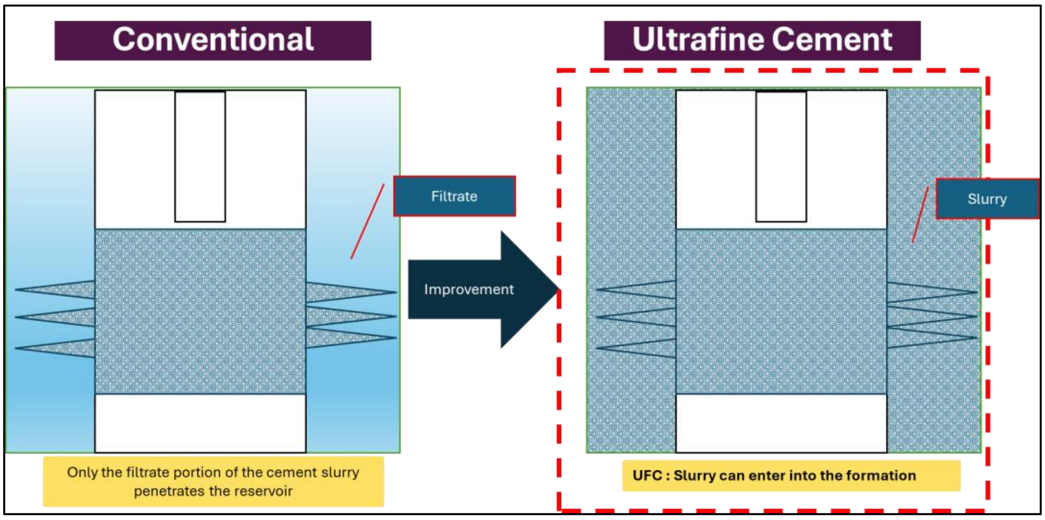

Figure 3. Comparison of Cement Slurry Performance in Tight Formation Penetration

II. METHODS

This study employed a comprehensive diagnostic and evaluation approach to optimize water shut-off operations using ultrafine cement in tight formations of the Talang Akar Formation (TAF) within Ramba Field. The methodology is structured into three major stages: data acquisition and preparation, qualitative and quantitative analysis, and field implementation followed by performance evaluation.

Data Acquisition and Preparation

Data utilized in this study include daily production history, Cement Bond Log (CBL), Variable Density Log (VDL), Ultrasonic Imaging Tool (USIT), Modular Formation Dynamics Tester (MDT), and Chan diagnostic plots. Candidate wells, RTA-01 and SNA-01, were selected based on their high water cut levels and indicators of compromised well integrity. Data were processed and verified to ensure consistency prior to further analysis.

Diagnostic and Analytical Evaluation

Water production anomalies were analyzed using Chan's diagnostic plots (WOR and WOR' vs. time) to classify the underlying water breakthrough mechanisms such as water coning or channeling. These results were further supported by Chan Diagnostic Plots, which for RTA-01, indicated a shift from water coning to near-wellbore channeling. This diagnosis validated the decision to proceed with targeted water shut-off using ultrafine cement.

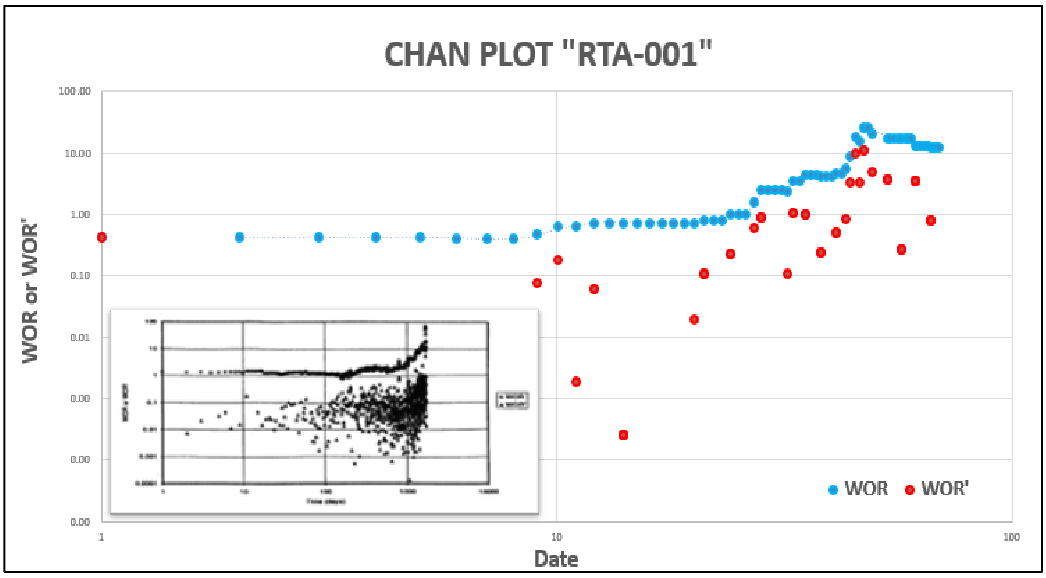

Figure 4. Water Diagnostic Analysis Well RTA-001

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CBL-VDL and USIT logs were interpreted to assess cement bonding quality and to identify microannuli or potential thief zones behind casing. Poor bonding was indicated by CBL amplitude >10 mV and bond index <0.6. Compressive strength estimations were derived from CBL interpretations using industry standard charts.

After bonding repairs were carried out using Class G cement, qualitative results showed that there was a good cement barrier bonding with a CBL value of <10 mV (Good Bonding) at several points in the well depth. In contrast to the USIT reading results, there are still nodes/bright colors at a depth of 1208-1211 mmD, which indicates a large possibility of channeling.

In the SNA-01 well, from the CBL analysis around the TAF-C layer (1201-1206 mMD) it already has good bonding with a value of <10 mV at the top of the layer, but at the bottom of the TAF-C layer (1201-1206 mMD) it has a bad bonding value of >10 mV (Figure 5.8). The results of the Log Interpretation Charts analysis from a depth of 1196-1212 mMD, the SNA-01 well has an average compressive strength value of 170 psi (bad bonding), an average bond index value of 0.49 (bad bonding), the average VDL to casing reading is classified as bad bonding

Additionally, open-hole log correlations were conducted to evaluate stratigraphic continuity and reservoir properties, particularly in target zones around TAF-C. These correlations supported the decision-making process for squeeze intervals and expected depth windows.

Laboratorium Test

Several laboratory tests were conducted to evaluate the performance and properties of ultrafine cement used for remedial water shut-off in tight reservoir formations. The primary tests included compressive strength testing, bond strength measurement through bond index analysis, particle size distribution, and cement slurry rheology. Compressive strength tests were performed at different curing ages to assess the rapid strength development of the ultrafine cement, ensuring its suitability for immediate zonal isolation requirements. Bond strength was evaluated by measuring the cement bond index using sonic logging simulation and laboratory bonding tests, which quantified the adhesion quality between cement and formation interfaces.

Test	Ultra fine Cement	Class G Cement
Yield	1.021 Cuft/sack	1.794 Cuft/sack
API Mixing Time	30 seconds	27 seconds
Fluid Loss	22 cc / 30 min/ 1000 psi	46 cc / 30 min/ 1000 psi
PV / YP @ 80 deg F	51.8 / 26.3	28.5 / 16.5
Gel Strength 10'/10" @ 80 degF	11 / 36	10 / 24
PV / YP @ 180 deg F	48 / 20	27 / 14
Gel Strength 10'/10" @180 degF	10 / 28	8 / 20
Thickening Time @ 70bc	5 hours 14 minutes	7 hours 01 minutes
CS @ 500 psi	8 hours 15 minutes	8 hours 18 minutes
CS @ 24 hours	1942 psi	**1387 psi**
Permeability Test	Using Sand 20/40, Cement Injection 50mL, Pressure 1000psi, Time 10 minutes **Ultrafine cement able to penetrate into the sand 20/40 matrix** 	Using Sand 20/40, Cement Injection 50mL, Pressure 1000psi, Time 10 minutes **Class G cement unable to penetrate into the sand 20/40 matrix** 

Figure 5. Laboratorium Test of Ultrafine Cement

Particle size analysis was conducted using laser diffraction techniques to confirm the finer granulometry of the ultrafine cement, typically in the range of 3-5 microns, compared to conventional API class G cement of around 325 Mesh, thus ensuring improved penetration ability into microchannels and pore throats. Rheological properties, such as slurry viscosity and flowability, were assessed to optimize pumping and placement procedures during cementing operations. These laboratory assessments provided critical data to tailor the cement slurry design for effective sealing of microchannels and to verify that the ultrafine cement meets the mechanical and bonding requirements necessary for successful remedial cementing in challenging reservoir conditions.

Squeeze Cementing Design and Execution

Remedial cementing was performed using ultrafine cement with a specific gravity of 13 ppg and particle size of 3–5 microns (approximately 1000 mesh). This slurry was selected based on its superior injectivity and ability to penetrate microchannels. Cement placement was designed using low-pressure squeeze techniques and job parameters such as slurry volume, injection rate, maximum allowable surface pressure (MASP), and thickening time were calculated using standard cementing models.

- RTA-01: Cement placed at 1209–1211 and 1218–1220 mMD; total slurry: 7.48 bbl; squeeze volume: 3.21 bbl; MASP: 806 psi.

Cement Volume Calculation inside Casing		
Interval perfo (margin)	34.0	m
nt slurry	4.27	bbl
Cement Volume Calculation for *Squeeze*		
total lubang perforasi	33	hole
ement squeeze	3.21	bbl
Dead Volume	1.00	bbl
Total Volume of Cement Slurry Required	7.48	bbl
Mixed Cement	8.48	bbl
Total Sax Cement Required	39.66	sack
	40	sack

Additive		Concentration		Total	
Ultrafine Cement "Type G"	CEMENT			40.0	sack
Fresh water		4.230	gps	169	gal
				4	bbl
Foam preventer	FP-9LS	0.010	gps	0.40	gal
Dispersant	CD-37LS	0.110	gps	4.40	gal
Fluid loss additive	FL-47LS	1.200	gps	48.00	gal
Bonding agent	BA-58L	1.300	gps	52.00	gal
Retarder	R-21L	0.003	gps	0.12	gal
TOTAL ADDITIVE				104.92	gal
				2.50	bbl
Total Mix Fluida		6.853	gps	274.1	gal
				6.53	bbl

- SNA-01: Cement placed at 1207–1209 mMD; total slurry: 6.35 bbl; squeeze volume: 3.21 bbl; MASP: 827 psi.

Cement Volume Calculation inside Casing		
Interval perfo (margin)	25.0	m
nt slurry	3.14	bbl
Cement Volume Calculation for *Squeeze*		
total lubang perforasi	33	hole
ement squeeze	3.21	bbl
Dead Volume	1.00	bbl
Total Volume of Cement Slurry Required	6.35	bbl
Mixed Cement	7.35	bbl
Total Sax Cement Required	34.37	sack
	35	sack

Additive		Concentration		Total	
Ultrafine Cement "Type G"	CEMENT			35.0	sack
Fresh water		4.230	gps	148	gal
				4	bbl
Foam preventer	FP-9LS	0.010	gps	0.35	gal
Dispersant	CD-37LS	0.110	gps	3.85	gal
Fluid loss additive	FL-47LS	1.200	gps	42.00	gal
Bonding agent	BA-58L	1.300	gps	45.50	gal
Retarder	R-21L	0.003	gps	0.11	gal
TOTAL ADDITIVE				91.81	gal
				2.19	bbl
Total Mix Fluida		6.85	gps	239.9	gal
				5.71	bbl

Post-job pressure tests were performed in accordance with the guidelines outlined in API Recommended Practice 53 (API RP 53), which provides standardized procedures for verifying the integrity of cementing operations, maintaining 200–300 psi over a 5-minute duration.

Performance Monitoring and Evaluation

Post-treatment evaluation was performed using CBL-VDL logs to quantify improvements in cement bond quality. The following parameters were observed:

- Amplitude reduction to <10 mV
- Compressive strength >500 psi
- Bond index improved to ≥0.5≥1 (medium to good bonding)

III. RESULTS AND DISCUSSION

The implementation of ultrafine cement in RTA-01 and SNA-01 wells in the Ramba Field yielded significant improvements in both well integrity and production performance. Prior to the cementing job, both wells were exhibiting abnormally high water cuts—100% in RTA-01 and 99.5% in SNA-01—primarily due to channeling and poor cement bonding behind casing.

Cement Bond Evaluation

Comprehensive cement bond evaluations were performed using Cement Bond Log (CBL), Variable Density Log (VDL), and Ultrasonic Imaging Tool (USIT). The initial CBL readings in RTA-01 showed an average compressive strength of 701 psi and a bond index of 0.57—values indicative of poor bonding. USIT confirmed the presence of micro-annuli and channeling around 1208–1211 mMD. SNA-01 exhibited even weaker bonding conditions, with an average compressive strength of 170 psi and bond index of 0.49 in the interval 1196–1212 mMD.

Post-treatment evaluations demonstrated substantial improvement:

- **RTA-01** (1202.5–1205.5 mMD): Compressive strength = 1051 psi; Bond Index = 0.76 (medium to good bonding).

Before

NO	Depth	Amplitude	Anttenuation	CS	Analisa CS	Bond Index	Analisa BI
	m	mv	dB/m	Psi			
1	1196	5	25.5	950	GOOD	1.00	GOOD
2	1197	5	25.5	950	GOOD	1.00	GOOD
3	1198	5	25.5	950	GOOD	1.00	GOOD
4	1199	7	22.5	535	GOOD	0.88	GOOD
5	1200	7	22.5	535	GOOD	0.88	GOOD
6	1201	9	20	500	GOOD	0.78	MEDIUM
7	1202	25	10	60	BAD	0.39	BAD
8	1203	20	12	150	BAD	0.47	BAD
9	1204	23	11.5	90	BAD	0.45	BAD
10	1205	20	12	150	BAD	0.47	BAD
11	1206	30	9	50	BAD	0.35	BAD
12	1207	30	9	50	BAD	0.35	BAD
13	1208	25	10	60	BAD	0.39	BAD
14	1209	35	8	42	BAD	0.31	BAD
15	1210	30	9	50	BAD	0.35	BAD
16	1211	30	9	50	BAD	0.35	BAD
17	1212	25	10	60	BAD	0.39	BAD
		22.57	12.46	170.14		0.49	

After

NO	Depth	Amplitude	Anttenuation	CS	Analisa CS	Bond Index	Analisa BI
	m	mv	dB/m	Psi			
1	1196	2	34	2350	GOOD	1.00	GOOD
2	1197	2	34	2350	GOOD	1.00	GOOD
3	1198	2	34	2350	GOOD	1.00	GOOD
4	1199	2	34	2350	GOOD	1.00	GOOD
5	1200	2	34	2350	GOOD	1.00	GOOD
6	1201	2	34	2350	GOOD	1.00	GOOD
7	1202	5	25.5	950	GOOD	0.75	MEDIUM
8	1203	5	25.5	950	GOOD	0.75	MEDIUM
9	1204	5	25.5	950	GOOD	0.75	MEDIUM
10	1205	2	34	2350	GOOD	1.00	GOOD
11	1206	1	41	2850	GOOD	1.21	GOOD
12	1207	1	41	2850	GOOD	1.21	GOOD
13	1208	1	41	2850	GOOD	1.21	GOOD
14	1209	2	34	2350	GOOD	1.00	GOOD
15	1210	5	25.5	950	GOOD	0.75	MEDIUM
16	1211	30	9	50	BAD	0.26	BAD
17	1212	25	10	60	BAD	0.29	BAD
		6.3	29.6	1729.3		0.87	

- **SNA-01** (1196–1212 mMD): Compressive strength = 1729 psi; Bond Index = 0.87 (good bonding)

Before

NO	Depth	Amplitude	Anttenuation	CS	Analisa CS	Bond Index	Analisa BI
	m	mv	dB/m	Psi			
1	1206	4	27.5	1250	GOOD	0.81	GOOD
2	1207	3	30.5	1565	GOOD	0.90	GOOD
3	1208	10	21	570	GOOD	0.62	MEDIUM
4	1209	11	19	475	BAD	0.56	MEDIUM
5	1210	9	20	500	GOOD	0.59	MEDIUM
6	1211	5	25.5	950	GOOD	0.75	MEDIUM
7	1212	2	34	2350	GOOD	1.00	GOOD
8	1213	2	34	2350	GOOD	1.00	GOOD
9	1214	11	19	475	BAD	0.56	MEDIUM
10	1215	9	20	500	GOOD	0.59	MEDIUM
11	1216	4	27.5	1250	GOOD	0.81	GOOD
12	1217	9	20	500	GOOD	0.59	MEDIUM
13	1218	30	9	50	BAD	0.26	BAD
14	1219	38	6	30	BAD	0.18	BAD
15	1220	23	11.5	90	BAD	0.34	BAD
16	1221	23	11.5	90	BAD	0.34	BAD
17	1222	15	15.5	215	BAD	0.46	BAD
		13.64	19.46	701.79		0.57	

After

NO	Depth	Amplitude	Anttenuation	CS	Analisa CS	Bond Index	Analisa BI
	m	mv	dB/m	Psi			
1	1206	10	21	570	GOOD	0.62	MEDIUM
2	1207	10	21	570	GOOD	0.62	MEDIUM
3	1208	9	20	500	GOOD	0.59	MEDIUM
4	1209	3	30.5	1256	GOOD	0.90	GOOD
5	1210	2	34	2350	GOOD	1.00	GOOD
6	1211	3	30.5	1256	GOOD	0.90	GOOD
7	1212	2	34	2350	GOOD	1.00	GOOD
8	1213	3	30.5	1256	GOOD	0.90	GOOD
9	1214	5	25.5	950	GOOD	0.75	MEDIUM
10	1215	5	25.5	950	GOOD	0.75	MEDIUM
11	1216	4	27.5	1250	GOOD	0.81	GOOD
12	1217	9	20	500	GOOD	0.59	MEDIUM
13	1218	9	20	500	GOOD	0.59	MEDIUM
14	1219	7	22.5	535	GOOD	0.66	MEDIUM
15	1220	8	21	535	GOOD	0.62	MEDIUM
16	1221	9	20	500	GOOD	0.59	MEDIUM
17	1222	8	21	535	GOOD	0.62	MEDIUM
		5.5	25.89285714	1051.64		0.76155462	

Amplitude readings dropped below 10 mV, indicating excellent bonding quality in both wells.

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Production Performance

Following squeeze cementing with ultrafine cement (13 ppg, 3–5 micron particle size), production tests revealed marked improvements. Based on post-treatment production performance, **Well RTA-01**, which was brought back into production using an Electric Submersible Pump (ESP), achieved an average gross production of 1120 BLPD, with a net oil rate of 34 BOPD and a water cut of 97%. This represents a production gain of 34 BOPD and a reduction in water cut from 100% to 97%.

In comparison, **Well SNA-01**, also produced using ESP, recorded an average gross production of 917 BLPD, with a net oil rate of 156 BOPD and a water cut of 83%. The oil production increased by 151 BOPD, and the water cut was successfully reduced from 99.5% to 83%, meeting the target objectives of the water shut-off intervention.

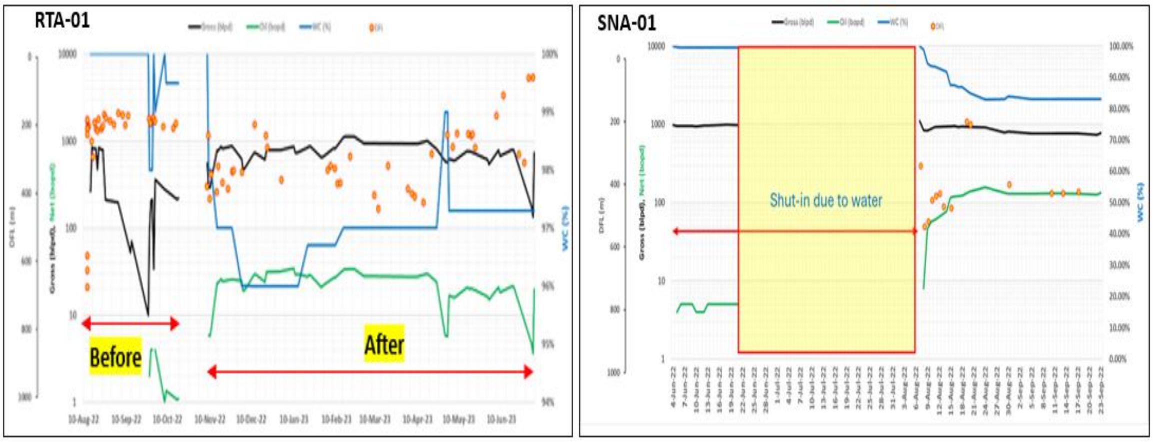

Figure 6. Production Performance After Ultrafine Cement Application

IV. CONCLUSION

Based on the research conducted, the following conclusions can be drawn:

1. Wells RTA-01 and SNA-01 experienced high water cut issues primarily due to inadequate well integrity that conventional Class G cement was ineffective in improving bonding in the tight Talang Akar Formation, which is characterized by a high injectivity factor (>2000).
2. Diagnostic analysis, including CBL-VDL and Chan plots, confirmed the presence of near-wellbore channeling and poor cement bonding, especially in RTA-01.
3. Ultrafine cement, with particle sizes ranging from 3 to 5 microns (approximately 1000 Mesh), was selected for remedial cementing due to its superior penetration capability in micro-annuli and tight formations.
4. Squeeze cementing was successfully applied in both wells using ultrafine cement at a specific gravity of 13 ppg, achieving proper zonal isolation and pressure test compliance per API Recommended Practice 53 (200–300 psi for at least 5 minutes).
5. Post-job CBL-VDL logs showed significant improvements in bonding quality:
   - RTA-01: Compressive strength increased to 1051 psi and bond index to 0.76
   - SNA-01: Compressive strength reached 1729 psi and bond index to 0.87

   Production performance also improved:
   - RTA-01: Oil rate increased by 34 BOPD, and water cut reduced from 100% to 97%
   - SNA-01: Oil rate increased by 151 BOPD, and water cut dropped from 99.5% to 83%

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