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Low Density Proppant in Slickwater Applications Improves Reservoir Contact and Fracture Complexity - A Permian Basin Case History

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Outline

Introduction

Ultra Lightweight Ceramic (ULWC) Proppant

1. Physical properties
2. Laboratory testing

Proppant Transport Evaluation

1. Stokes Law calculations
2. Slot Experiment and Results

ULWC field application – Permian Basin Case History

1. Operational considerations
2. Well performance

Summary and Conclusions

Introduction

Background - Slickwater Fracturing (SWF) on the rise in recent years

Drivers for design evolution include

1. Proppant pack damage minimization
2. Formation complexity
3. Environmental concerns.
4. Cost

Limitation of SWF - Proppant carrying capacity

Design requirements for successful SWF

1. Large water volume requirement
2. Limited max proppant concentration (0.25 – 2.00 PPA)
3. Smaller mesh size proppant (100 – Mesh & 40/70)

Ultra Lightweight Ceramic (ULWC) proppant

ULWC design goals

1. Low density proppant
2. Increased fracture coverage (same mass ULWC, lbm)
3. Reductions in pump time, water + chemical usage (with same volume ULWC, cu. ft)

Table 1 – Physical characteristics of ULWC and sand

Property	ULWC	Sand	IDC
ASG	**2.0**	2.65	3.25
BD (g/cc)	1.15	1.56	1.88
BD (lbm/ft^3)	72	97	117
Roundness	0.9	0.6 – 0.7	0.9
Sphericity	0.9	0.6 – 0.7	0.9

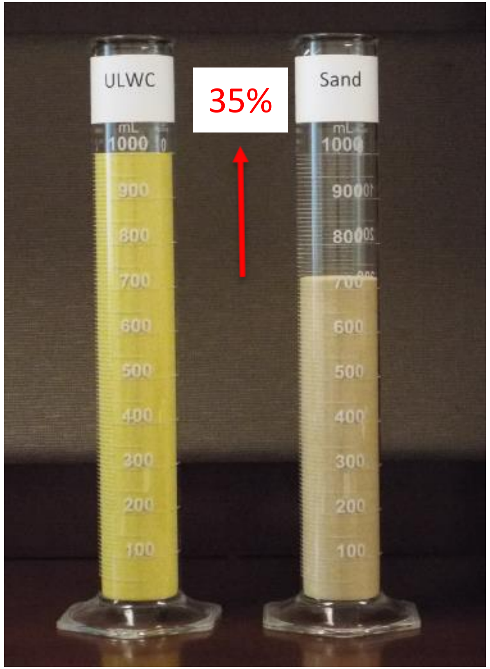


Fig. 1 – Equal mass of ULWC and sand

Long Term Conductivity Comparison of ULWC with Sand

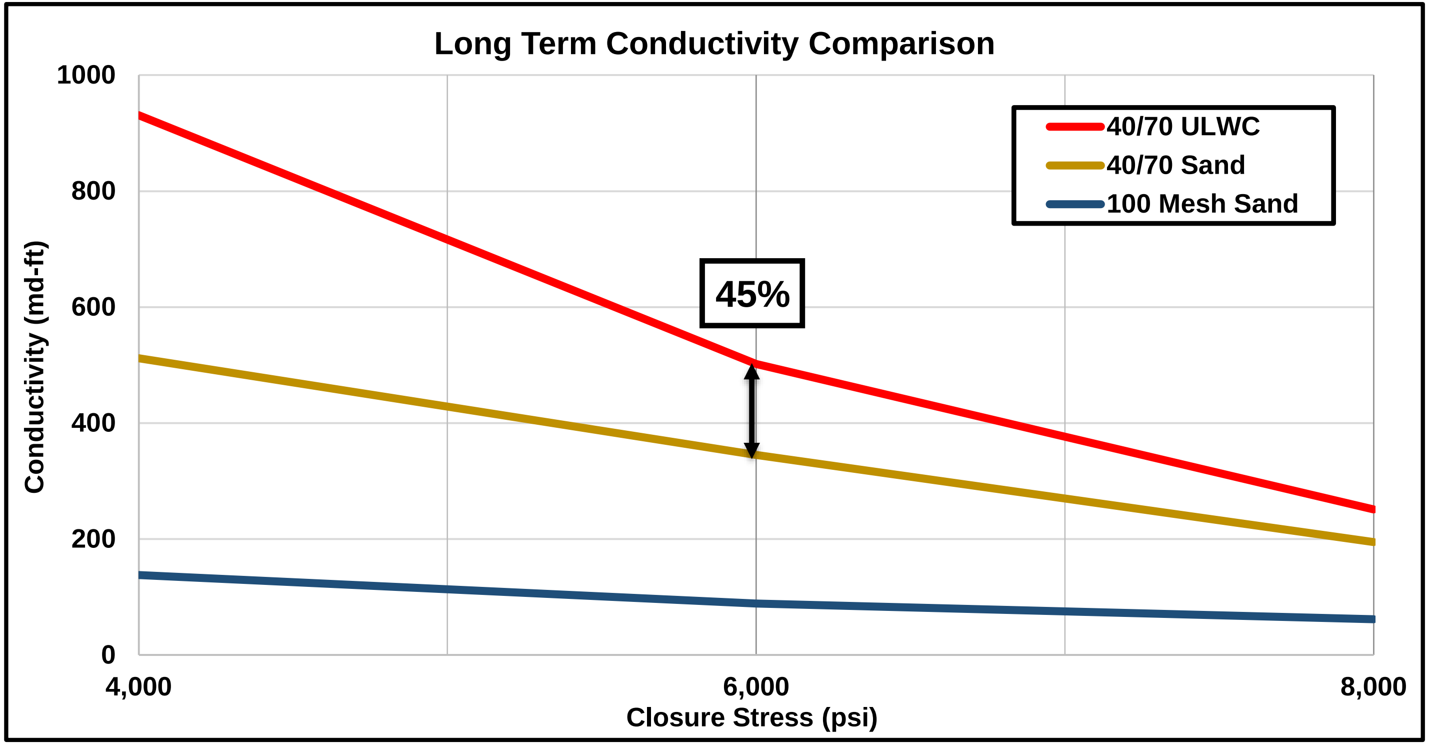


Fig. 2 - Long Term Conductivity Comparison of ULWC with 100-Mesh sand and 40/70 Frac Sand

Proppant Transport – Static Conditions

$$V_s = \frac{g(\rho_P - \rho_{fluid})d_P^2}{18\mu_{fluid}}$$

(Fresh water, 1 cp)

Stoke's Law

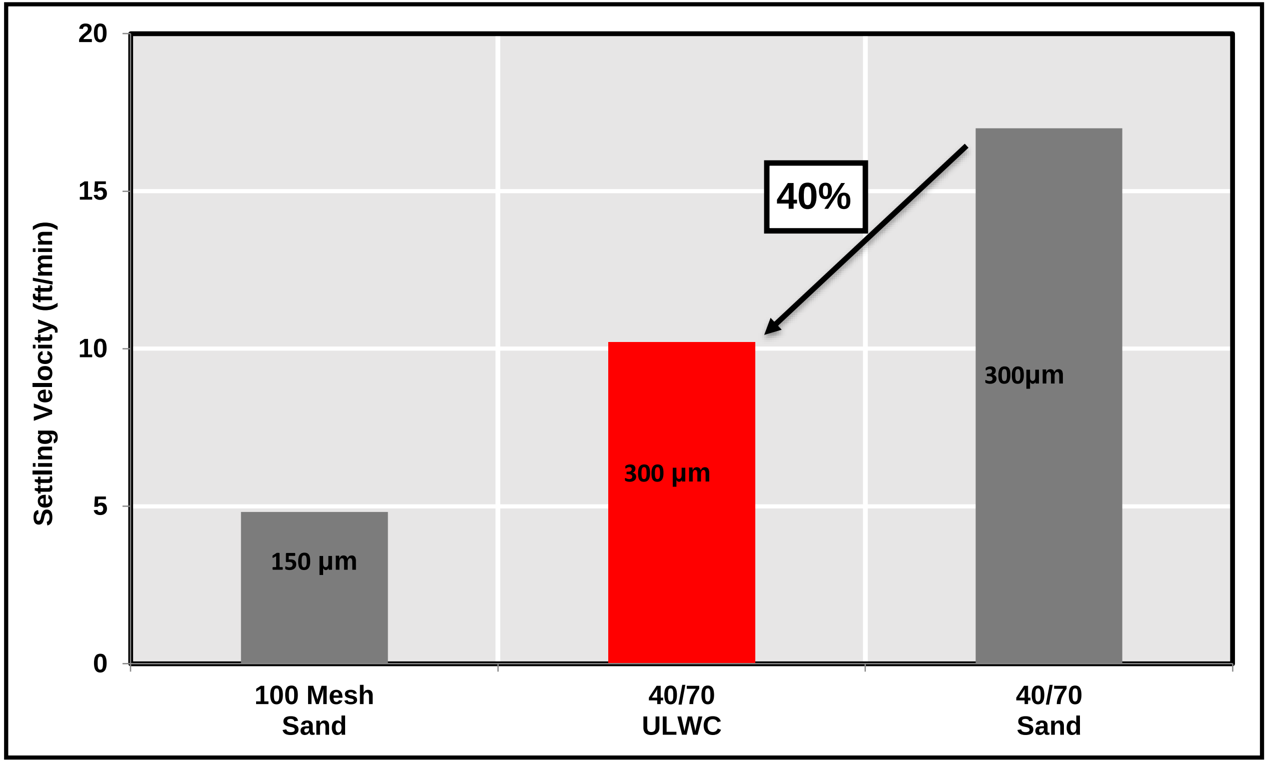


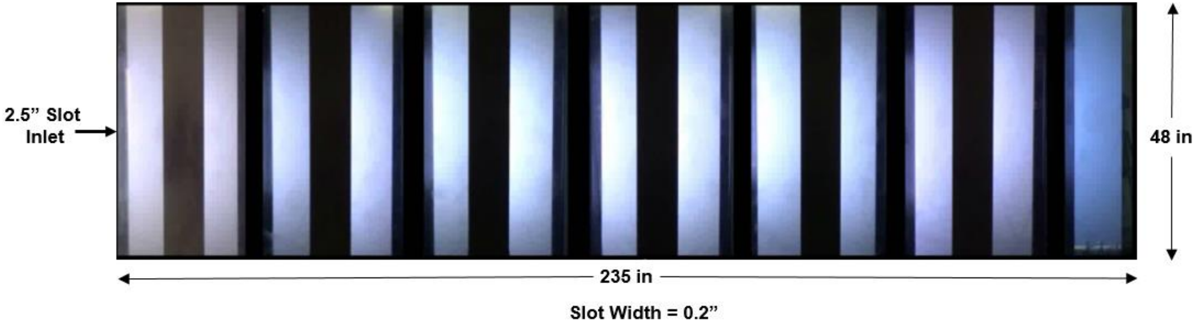
Fig. 3 – Settling velocity comparison of 40/70 ULWC with 100-Mesh sand and 40/70 sand

Proppant Transport – Dynamic conditions

Slot testing used to evaluate transportability under pumping conditions

Major test apparatus

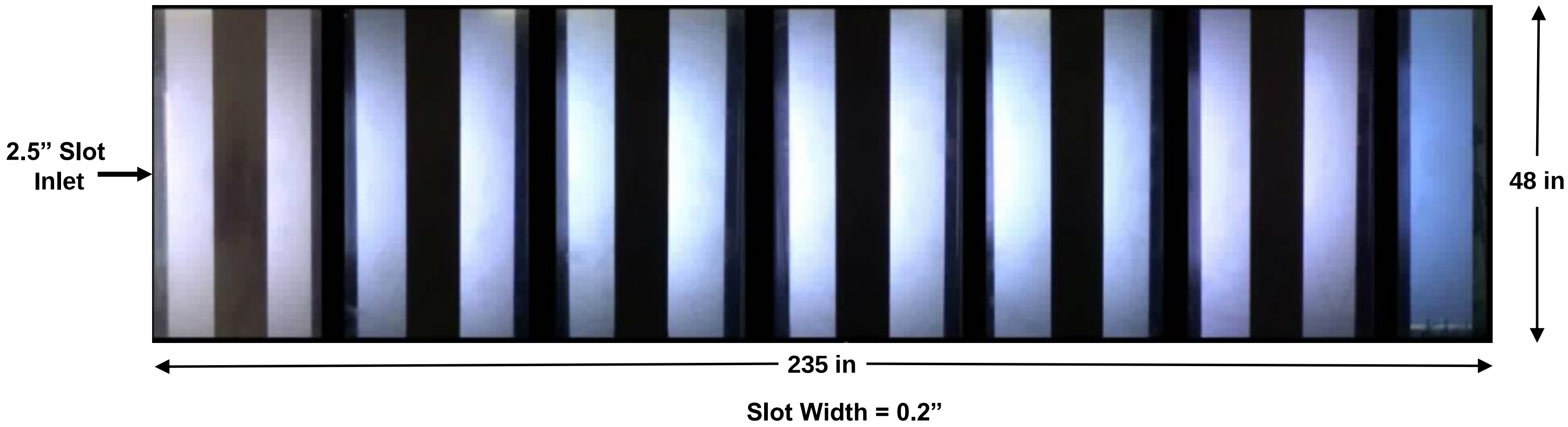
1. Water pumps, reservoirs
2. Flowlines, flowmeters
3. Pressure transducers
4. Catch tanks
5. Digital cameras



4 different test scenarios (Similar volume)

1. Test 1 - 40/70 Sand
2. Test 2 - 40/70 ULWC
3. Test 3 - 50:50 (by volume) mixture of Sand and ULWC
4. Test 4 - Alternating stages (Sand:ULWC:Sand:ULWC)

Proppant Transport – Slot Flow



Performance indicators

1. Proppant profile/geometry in slot
2. Water requirement
3. Far-field sample size

Test Conditions

1. Freshwater system (ambient T, P)
2. Slurry rate 10.5 gpm
3. Slurry concentration 2 PPA
4. Equivalent proppant volumes

Slot Testing Results - Tests 1 & 2

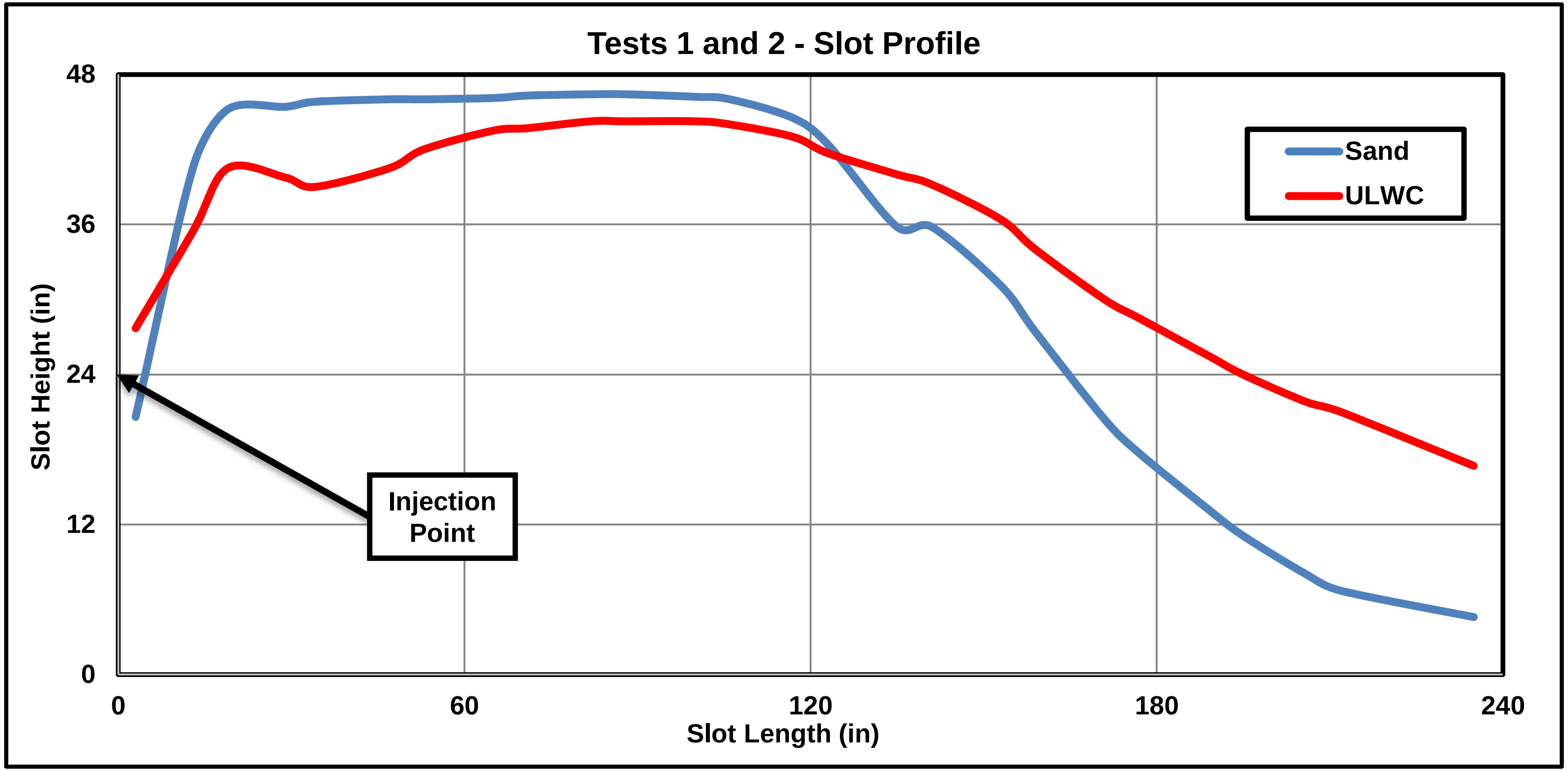


Fig. 4 - Slot Profile for Tests 1 & 2

Slot Testing Results - Tests 3 & 4

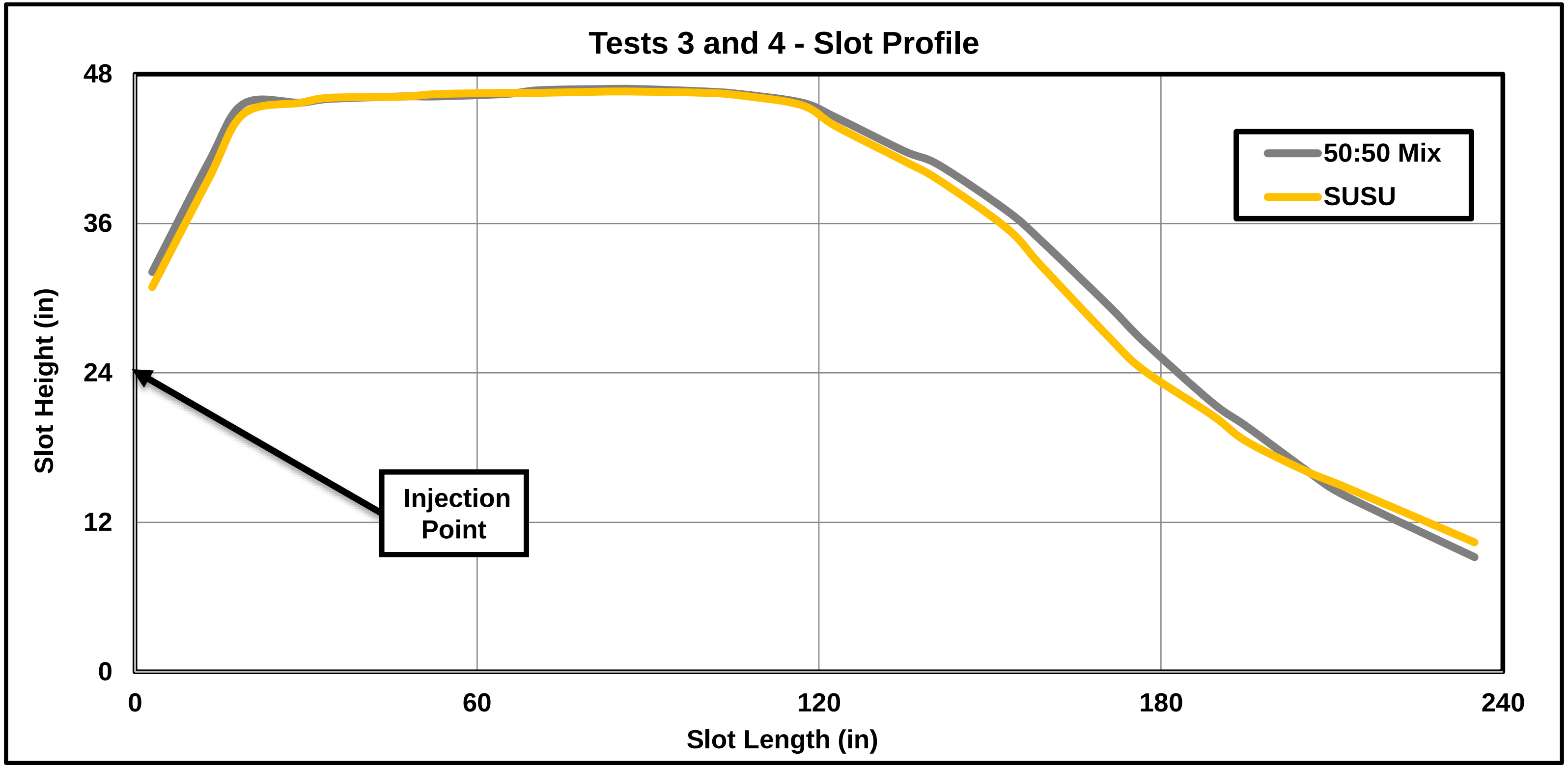


Fig. 6 - Slot Profile for Tests 3 & 4

Proppant Transport Evaluation – Test 4

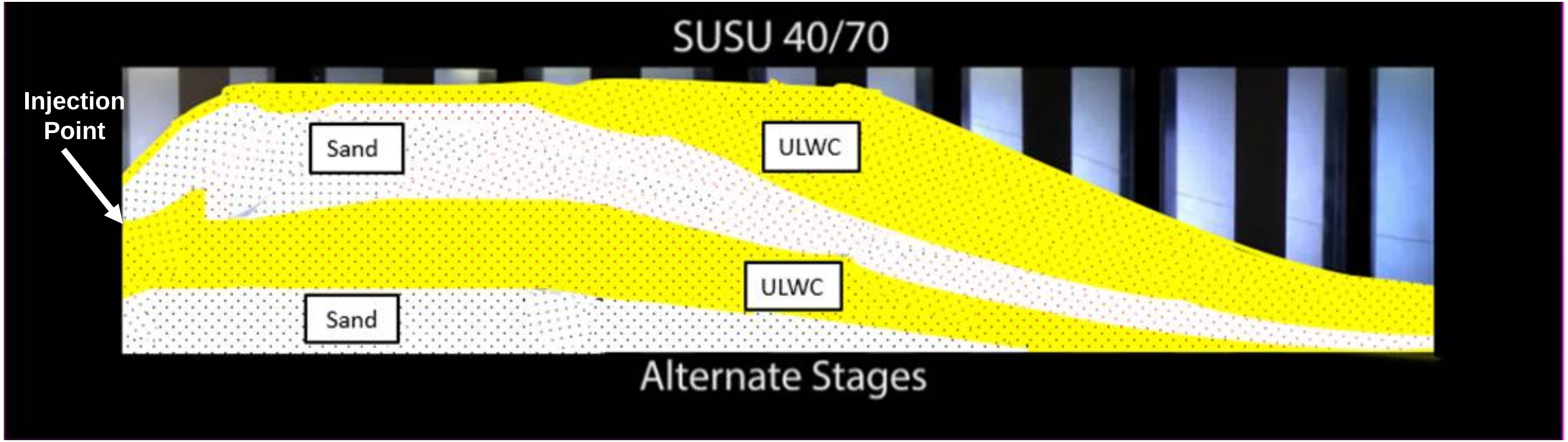


Fig. 8 - Slot sections schematic during Test 4, showing the geometry of Sand and ULWC

- Sand settled early in the near-field
- ULWC “launches” over settled sand
- Conductivity channels in settled sections

Slot Testing Results – Overall Profile

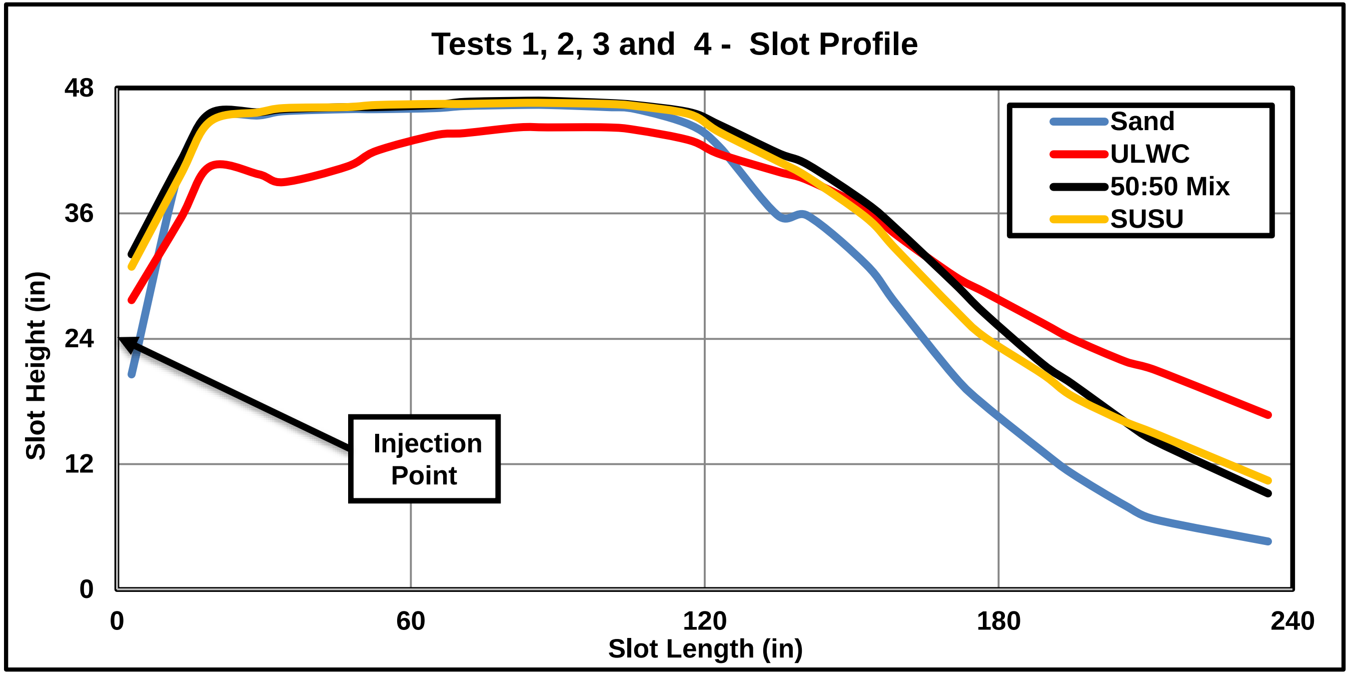


Fig. 7 – Overall slot Profile for Tests 1,2,3 & 4

- 100% ULWC has 4x the far-field height of sand
- Mix and S-U-S-U : 2x height of sand in the far-field

Slot Testing Results - Summary

Table 2 – Slot Flow Results

Test	Sample	*Mass Pumped (lb)	*Areal Coverage (sq. ft)	Water Usage (gals)	**ULWC discharged (lb)	**Sand discharged (lb)
1	ULWC	74.4	58.1	37.20	3.82	-
2	Frac Sand	98.6	55.8	51.20	-	1.21
3	50:50 Mix	86.5	57.1	46.40	2.62	-
4	S-U-S-U	86.5	56.3	46.10	1.44	0.65

1. Equivalent proppant volume in Tests 1 & 2 with ~30% less fluid (ULWC)
2. ~ 3X ULWC sample in far field
3. Similar fluid & geometry utilization in Tests 3 & 4

Permian Basin Case History – Well A

- “Wildcat” well located in the 2nd Bone Spring
- 100 ft gross thickness
- Previous success with 100 – Mesh and 40/70 sand
- Design goal – fracture length

Typical Treatment Plot for Well A

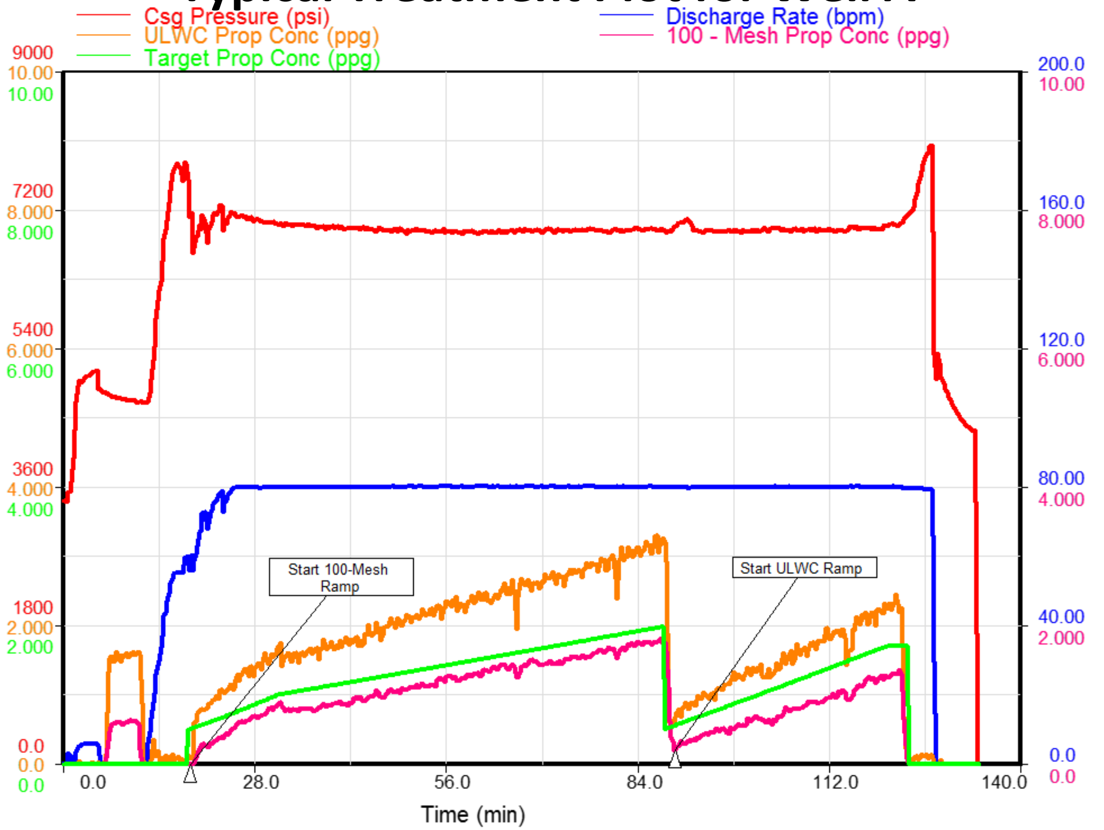


Fig. 9 – Typical treatment plot for Well A, showing a lead-in with 100-Mesh sand and a tail-in with ULWC

Well A – Well Performance

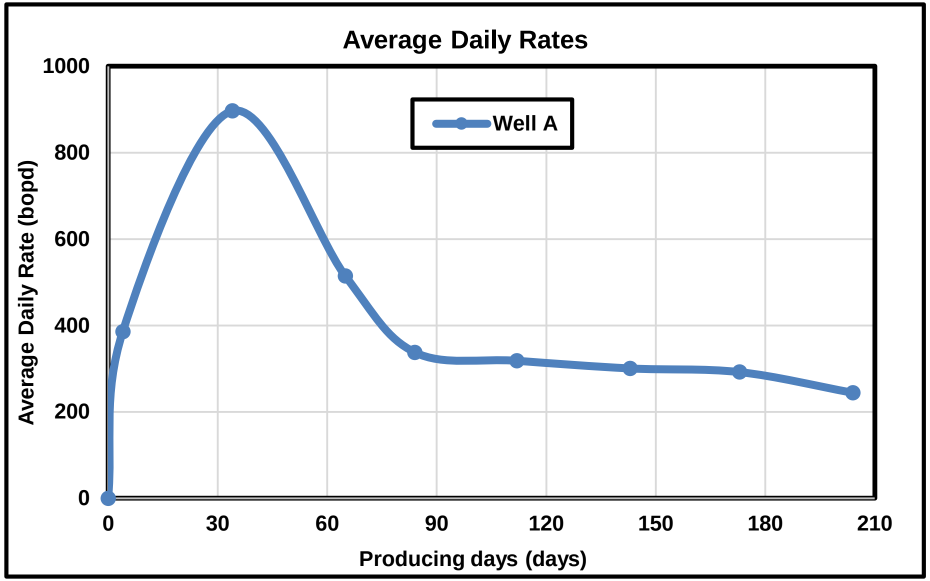


Fig. 10a - Average daily rate plot

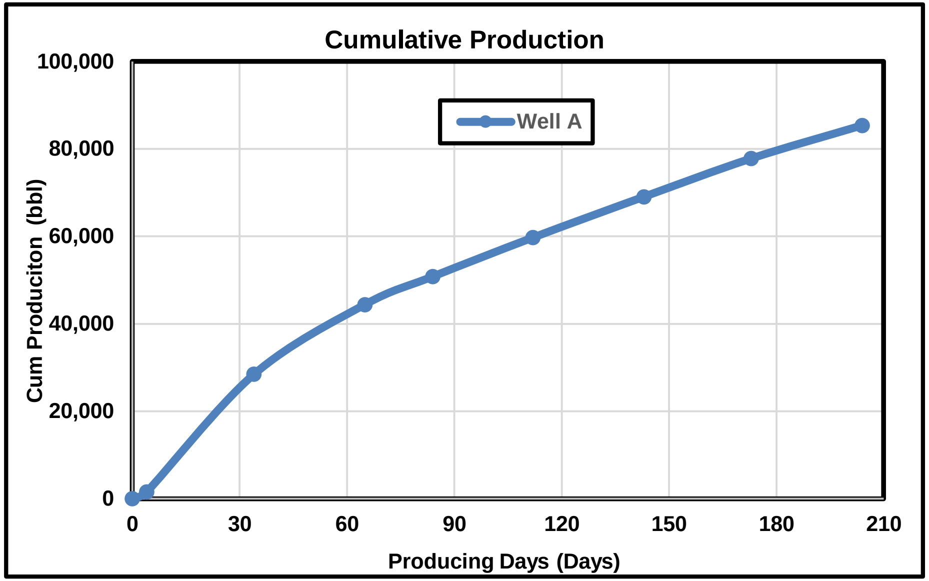


Fig. 10b - Cumulative production plot

Summary and Conclusions

- SWF has become very popular
- Proppant transport is problematic in SWF
- A new low density (2.0 ASG), high transport proppant has been developed
- 25% lighter than sand with higher conductivity
- Slot flow testing confirms improved transport, leading to increased fracture geometry
- First deployment in Permian well was successful
- Several novel applications available

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