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Cementing Paradigm Shift:
A Local Solution to a Global Problem

David J. Mack, Marathon Oil Co., SPE
Outline

- Introduction
- Cement strength requirements
- Solving a consequential problem
- Lab workup
- Field examples
- Economics
- Conclusions
Introduction
Area of Interest
Introduction

Cement Job Objectives

- Cement across low frac gradient shales
- Provide zonal isolation for multiple pay zones
- Stand up to stresses incurred during hydraulic fracturing
- Economical
Introduction

History of Gas Shale Well Cementing

- Two-stage jobs
- Thixotropic slurries
- Microspheres
- Foam
- Silicate-extended
## Introduction

### Lightweight Silicate-Based Cement

<table>
<thead>
<tr>
<th>Density (ppg)</th>
<th>Yield (ft³/sk)</th>
<th>72-Hour Compressive Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.5</td>
<td>2.91</td>
<td>470</td>
</tr>
<tr>
<td>12.0</td>
<td>2.48</td>
<td>700</td>
</tr>
<tr>
<td>12.5</td>
<td>2.15</td>
<td>1,050</td>
</tr>
<tr>
<td>13.0</td>
<td>1.91</td>
<td>1,550</td>
</tr>
<tr>
<td>13.5</td>
<td>1.71</td>
<td>1,941</td>
</tr>
</tbody>
</table>
Cement Strength Requirements

- Normally consider only unconfined compressive strength
- 2,000 to 5,000 psi is typical requirement
- Tensile and flexural strength also important
- 8 psi tensile strength required to support a casing string (equates to approximately 100 psi compressive strength)
- Cracking failures are all but eliminated with the use of low-density and low-compressive strength cement
Introduction

Lightweight Silicate-Based Cement

- 12 ppg density
- Cement 4,000 feet plus in single stage
- Very economical versus two-stage cement jobs and other cement blends
- Used on over 2000 wells since 1998
Consequential Problem

◆ The problem:
  – Cement sheath with 700 psi compressive strength can’t be “seen” with conventional CBL logging equipment available in the Appalachian Basin
  – Longer waiting-on-cement time required for additional strength development
  – Result is several days of lost production per well
Free Pipe
Channel - ?
Good Bond
How Can We See The Cement?

- Compressive strength and acoustic attenuation relationship
  - Goal: 1,000 psi compressive strength should yield enough acoustic impedance to achieve attenuation
How Can We See The Cement?

Compressive strength and acoustic attenuation relationship.

1,000 psi compressive strength should yield enough acoustic impedance to achieve attenuation.
Lab Workup
Objectives For New Cement

- 1,000 psi compressive strength
- CBL must “see” it in 72 hours
- 12 ppg density
- Normal thickening time
- Easy to mix and pump
Lab Workup
Chemistry

- Compressive strength hurdle tough at first using Class A/Type I cement @ 12 ppg
- Pozzolan powder discovered to be effective at concentration up to 10%
- Changing portland cements to ASTM Type III cement played a large role in achieving compressive strength goal
## Lab Workup

### New Blend Slurry Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickening Time (hrs:mins)</td>
<td>2:41</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>80</td>
</tr>
<tr>
<td>Ramp (hrs:mins)</td>
<td>20</td>
</tr>
<tr>
<td>Pressure (psi)</td>
<td>1000</td>
</tr>
<tr>
<td>Free H2O (mls)</td>
<td>0</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>AMB</td>
</tr>
<tr>
<td>Angle (°)</td>
<td>90</td>
</tr>
<tr>
<td>FL Temp °F</td>
<td>600</td>
</tr>
<tr>
<td>Fluid Loss cc's/30 mins:</td>
<td>50.00</td>
</tr>
<tr>
<td>SFL Temp °F</td>
<td>10 sec</td>
</tr>
<tr>
<td>Ramp hrs:mins</td>
<td>10 min</td>
</tr>
<tr>
<td>Blow Out Values</td>
<td>10 min</td>
</tr>
<tr>
<td>min:sec cc's</td>
<td>1000 lbs/ft²</td>
</tr>
<tr>
<td>5000 lbs/ft² hrs:mins</td>
<td>hrs:mins</td>
</tr>
<tr>
<td>16: Gas Model</td>
<td></td>
</tr>
<tr>
<td>26: Tmp °F</td>
<td>Top</td>
</tr>
<tr>
<td>30: Pass / Fail</td>
<td>Densities lb/gal Bottom</td>
</tr>
<tr>
<td>UCA / Compressive Strength @ 50psi</td>
<td>1:45 hrs:mins</td>
</tr>
<tr>
<td>Final Time</td>
<td>1000 psi</td>
</tr>
<tr>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>4 hr:</td>
<td>749 psi</td>
</tr>
<tr>
<td>12 hr:</td>
<td>947 psi</td>
</tr>
<tr>
<td>24 hr:</td>
<td>1045 psi</td>
</tr>
<tr>
<td>48 hr:</td>
<td></td>
</tr>
<tr>
<td>72 hr:</td>
<td></td>
</tr>
</tbody>
</table>
## Lab Workup

### New Slurry Properties

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<tbody>
<tr>
<td>Thickening Time, Hr:Min</td>
<td>2:41</td>
</tr>
<tr>
<td>Temperature, °F</td>
<td>80</td>
</tr>
<tr>
<td>Pressure, psi</td>
<td>1000</td>
</tr>
<tr>
<td>Free Water @ 90°, ml</td>
<td>0</td>
</tr>
<tr>
<td>Time to 50 psi, Hr:Min</td>
<td>1:45</td>
</tr>
<tr>
<td>Time to 500 psi, Hr:Min</td>
<td>8:51</td>
</tr>
<tr>
<td>24 Hr Strength, psi</td>
<td>630</td>
</tr>
<tr>
<td>48 Hr Strength, psi</td>
<td>901</td>
</tr>
<tr>
<td>72 Hr Strength, psi</td>
<td>1010</td>
</tr>
</tbody>
</table>
Lab Workup

New Slurry Compressive Strengths
Field Example WV-1
Kanawha County, WV

Good bond log according to CBL/VDL over this interval toward the bottom of the hole. The log was run about 96 hours after the plug was down on the 4-1/2 production casing cement job.

195 sacks
TD = 5,750 ft.
Fill = 3,230 ft.
Field Example WV-2
Kanawha County, WV

Fair to good bond log according to CBL/VDL over this interval toward the bottom of the hole. The log was run about 80 hours after the plug was down.

184 sacks
TD = 5,499 ft.
Fill = 3,549 ft.
Economics Of...
Cycle Time Reduction

- 100 well program, IFP = 200 MSCF
- Gas sells for $5.00/MSCF
- Lost production days = ($1000)/day cash flow
- 5 days per well = 500 days/year
- 500 days x $1000/well = ($500,000)
Economics Of…
Cycle Time Reduction

- New slurry costs $1,500 more
- 100 wells x $1,500 = $150,000
- Reduce WOC time by 5 days per well
- Net value = $500k - $150k = $350k
Conclusions

- Cement does not need several thousand psi compressive strength
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- Cement blend @ 12 ppg achieved 1,000 psi in 72 hours
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- Cement blend @ 12 ppg achieved 1,000 psi in 72 hours
- New Pozzolan powder and switch to ASTM Type III cement proved to be effective in improving compressive strength of system
Conclusions

- Oilfield casing need not be cemented exclusively with API cements
Conclusions

- Oilfield casing need not be cemented exclusively with API cements
- Field application successful
Conclusions

- Oilfield casing need not be cemented exclusively with API cements
- Field application successful
- Cash flow improved for large program
This Point Forward

- API class cement may no longer be available
This Point Forward

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- Must develop cement blends using ASTM construction type cement.
This Point Forward

- API class cement may no longer be available
- Must develop cement blends using ASTM construction type cement.
- Look to other industries for potential solutions
This Point Forward

- API class cement may no longer be available
- Must develop cement blends using ASTM construction type cement.
- Look to other industries for potential solutions
- Change our paradigm
Thank You