Geopolymer-Based Proppants

Significance

Onshore activities in North America, including production from shale and other tight formations through the hydraulic fracturing ('fracking') process, are changing the dynamic of hydrocarbon energy markets around the world, bringing the USA to the verge of what was considered non-attainable only 15 years ago – energy independence. In order to fracture shale rock and open fissures to release oil and gas in a cost effective manner, proppants must be used to prop the fissures open so that oil and gas can be extracted through the openings, and allowed to flow into the wellbore with minimal obstruction.

Fracking is currently concentrated in North America where the industry is considered to be maturing. In 2012, North America dominated proppant consumption, with about an 80% share of the 24.4 million ton global proppant market. However, with hydraulic fracking technology expending around the globe, by 2017 global demand is expected to reach 43.8 million tons, with 75% of that volume expected to be consumed in North America.

Proppant market leaders and plant locations are scattered around the nation. Most operations utilize fracturing sand, resin-coated, or ceramic proppants provided by the few major suppliers listed in Table 1. Because the raw material sources for these products are unique, production facilities are tied to specific geographic locations. This often requires proppants to travel great distances between the manufacturing facility and the drilling site. Thus, it is not uncommon for transportation to represent up to 60 percent of a proppants' "at well site" costs.

Table 1: Major Proppant Suppliers

Manufacturer	Type	Location
Carbo Ceramics	Ceramic proppants	Macon, GA
Saint-Gobain	Ceramic proppants	Fort Smith, AR
Momentive	Resin-coated proppants	Columbus, OH
Badger	"Northern White" sand	Fairwater, WI

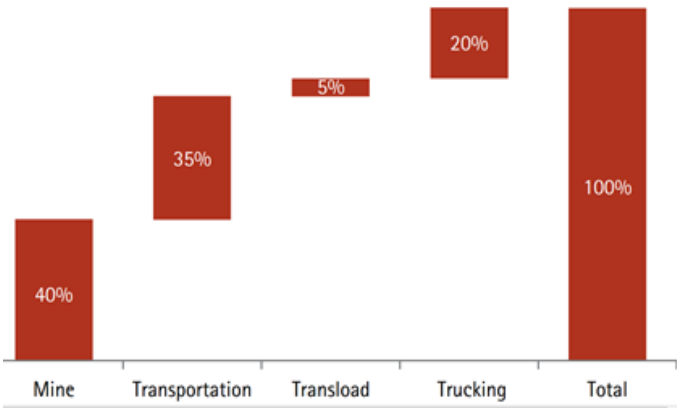

Fig. 1. cost components of proppant manufacture in the U.S.

Alchemy Geopolymer Solutions has developed fly ash geopolymer based proppant technology to support 'fracking' applications in tight shale formations. The manufacturing of geopolymer-based proppants presents a series of advantages that make the technology both, economically viable as well as provide it with a 'Green Appeal':

a) Nearly 30% of the tight oil, gas, and shale wells in the nation are located within 400 miles of AGS' primary source of fly ash, Dolet Hills GPS- a significant advantage over competitor products which must be transported from outside our region. Considering transportation cost represents as much as 60% of the cost of proppants to consumers, proximity to market represents a significant economic advantage. Oil and Gas producers are under significant pressure to cut costs and improve efficiency in a softening oil price environment. As such, the cost advantage represented by geopolymer-based proppants is likely to appeal to many producers striving to lower their breakeven point.

b) Fly ash based geopolymer has several intrinsic characteristics which are desirable in proppants; namely, low specific gravity, corrosion resistance, low cost and local availability.

c) The carbon footprint associated with geopolymer-based proppants is significantly smaller than that associated with engineered proppants due to a simpler and less energy consuming manufacturing process and lower ton-mile transportation footprint. The green appeal of Geopolymer-based proppants is aligned with recent innovations in the fracking industry, aimed at making the technology more environmentally friendly.

d) Geopolymer-based proppant technology opens the door to the conversion of hundreds-of-millions of tons of coal-ash and other byproducts of industrial incineration byproducts into valuable commercial product in a rapidly growing market.

Fig. 2. Geopolymer based-Proppants

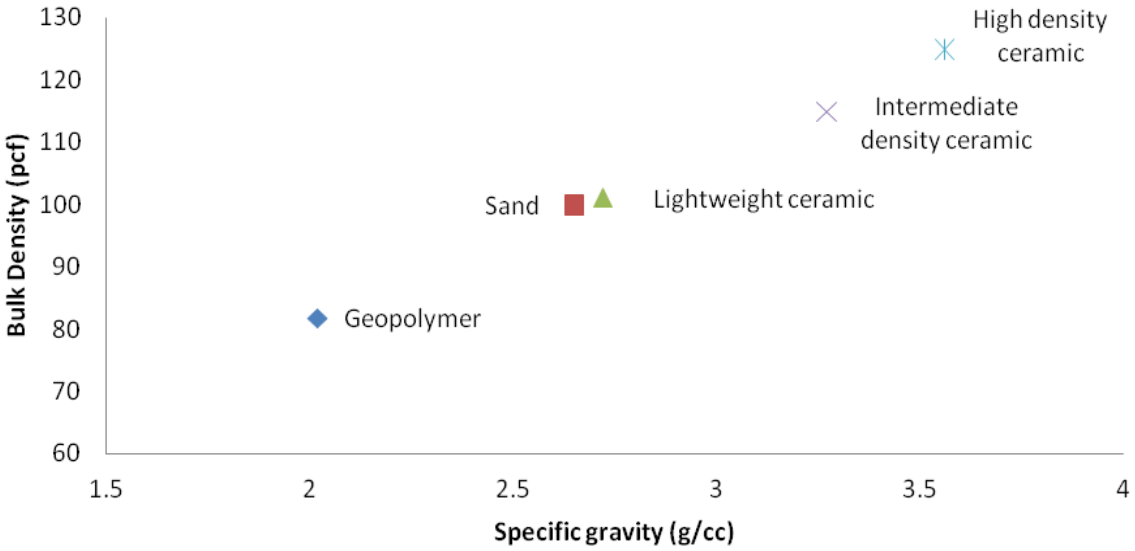

Fig. 3. Bulk density and specific gravity of Geopolymer-based and commercial proppants

Table 2 summarized the API recommended properties for proppant, typical performance values offered by commercially available proppants and performance values for ***Alchemy Geopolymer Solutions'*** Geopolymer-based proppant products. Our technology meets or exceeds API recommended values reported for commercially available products in six of the seven categories evaluated thus far, and is very close in meeting crush strength requirements. Currently implemented improvements are expected to reduce the maximum percent of fines by weight to 15%, making them suitable for hundreds of wells that are fracked at depths of less than one mile below the surface.

Table 2. API recommended/typical proppant properties

Property	API recommended values	Typical/Competitor	Results
Particle size distribution	Mesh 8/12, 10/20, 20/40, 70/140.	Mesh 20/40 or 40/70.	Mesh 20/40 or 40/70.
Sphericity and roundness	0.6 for both	0.9, 0.8	0.9, 0.8
Crush resistance	Max fines by weight at compressive stress between 4000 and 6000 psi. 6-12 mesh / 20% 16-30 mesh / 14% 20-40 mesh / 14% 30-50 mesh / 10%	Max fines by wt. @5000 psi 0.5% @7500 psi 2.0%	Max fines by wt. @5000 psi 22%
Acid solubility	<7% solubility in a solution of 12 parts HCl-4 parts HF	4.8% solubility in 12/3 HCI/HF	6.4% solubility in 12/3 HCl/HF
Turbidity	N/A	< 250 NTU	30 NTU
Bulk Density	Not specified	87-125 pcf	84 pcf
Apparent Specific Gravity	Not specified	2.5-3.5	1.34
Conductivity	Not specified	Depending on closure stress.	To be performed