Effect of ultrafine cement on the rheology properties and shrinkage of class H cement

R.Paulnath, and C. Vipulanandan[1], Ph.D., P.E.
Center for Innovative Grouting Material and Technology (CIGMAT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
E-mail: pcrajana@uh.edu, cvipulanandan@uh.edu Phone: 7134059507

Abstract: In this study ultrafine cement (UFC) was used as an additive to class H oil well cement with a water to cement ratio of 0.38. Ultrafine cement is used as grouting material .Ultrafine cement was mixed in the range of 0-8% of the total weight of the cement mixture. Rheological properties and shrinkage of the mixture was studied with the addition of ultrafine cement. Vipulanandan rheological model was used to characterize the behavior of the cement slurry. Addition of UFC increased the yield stress by and also the maximum shear stress limit. Addition of UFC reduced the shrinkage by 92 %.

1. Introduction: Ultrafine cement is considered to be the cements with a d_{95} 10 microns and a Blaine Fineness of at least 900 m^2 /kg. It is used as grouting material (Raymond and Nathan, 2010). Although the cost of ultrafine cement is typically five to ten times higher than ordinary portland cement (OPC), this higher cost is often more than offset by the advantages and overall superior performance of ultrafine cement-based grouts. (Raymond and Nathan,2010)

Gas leakage into and through the cemented annulus in oil and gas wells is a safety problem. The conditions for gas migration develop when the hydrostatic pressure of the hydrating cement slurry column slowly declines and finally falls below the pore pressure of a gas bearing formation. This pressure decline is mainly caused by chemical shrinkage of the cement. A low shrinkage will reduce the pressure decline and hence the risk of gas migration. (Lyomov, 1997)

2. Objective:
Overall objective was to investigate the effect of adding up to 8% of ultrafine cement to class H cement

3. Methods:
Specimens were prepared using class H cement and ultra-fine cement (UFC) with water-cement ratio of 0.38. UFC was added in 2%, 4%, 6% and 8% of the total weight of the cement mixture. After mixing, the cement was cast into the cylindrical molds with height of 4 inches and diameter of 2 inches. Specimens were cured for 1 day. Shrinkage of the cement was measured after 1 day of curing.The rheology tests were performed at temperature of 25°C and different mixture of cement were tested using a viscometer in the speed range of 0.3 to 600 rpm (shear strain rate of 0.5 s^{-1} to 1024 s^{-1}) and related shear stresses were recorded

Vipulanandan Rheological relationship between shear stress and shear strain rate was used to model the behavior of the mixture (3).

$$\tau=\tau_o + \dot{\gamma}/(A+D\dot{\gamma})$$

Where τ: shear stress (Pa); A $(Pa.\ s)^{-1}$ and D $(Pa)^{-1}$ are model parameters;

4. Results:

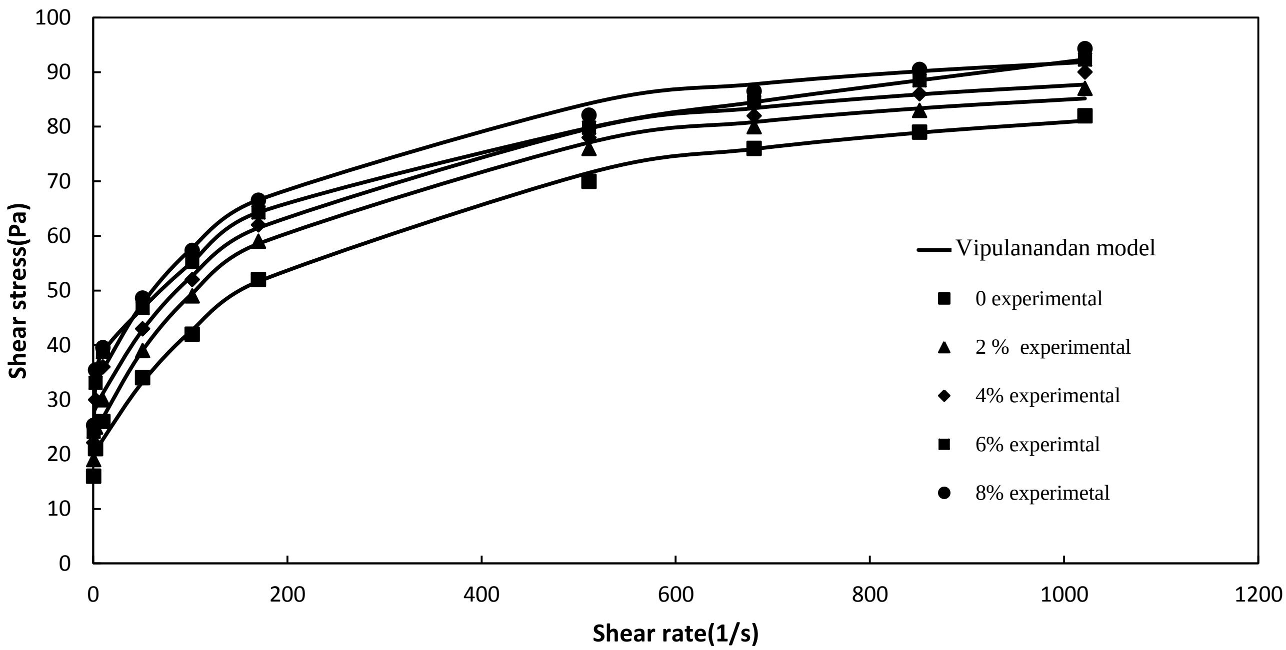

Figure 3 Shear Stress- Shear Strain rate Relationship for cement mixture with different percentages of UFC

Table 1: Model parameters for Vipulanandan rheological model

UFC (%)	τ_o(Pa)	A	B	τ_{max}(Pa)	τ_o/ τ_{max}	R^2	RMSE
0	19.5	3.043	0.01327	94.9	0.206	0.995	1.563
2	22.7	2.731	0.01364	96.1	0.237	0.994	1.745
4	27.5	2.627	0.01404	98.7	0.279	0.988	1.674
6	30.2	2.544	0.01428	100.2	0.301	0.986	1.436
8	31.6	2.446	0.01420	102.0	0.310	0.986	1.584

Addition of UFC increases the yield stress of the mixture according to Vipulanandan rheological model .This may be due to the larger surface area of UFC due to the smaller particle size. Maximum shear stress also increases with the addition of UFC. With the addition of 8% UFC, the yield stress increased from 19.5 Pa to 31.6 Pa, 62% increase. With addition of 8% UFC the maximum shear stress also increased from 94.9 Pa to 102 Pa, 7.4% increase. With the increase of UFC percentage, yield stress/maximum shear stress ratio increases.

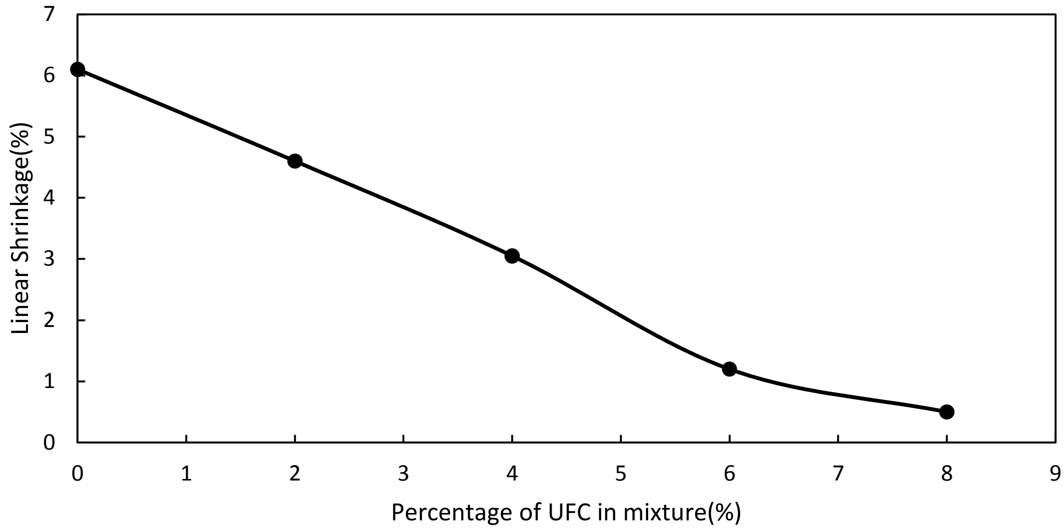

Fig 2: Shrinkage variation with the percentage of UFC

24 hour shrinkage of cement reduced with the addition of UFC. Addition of 8% UFC reduces shrinkage by almost 92%.

5. Conclusion:

1. Addition of 8% UFC decreased shrinkage in cement from 6% to 0.5%.
2. Addition of 8% UFC increased the yield stress of the mixture by 62% according to Vipulanandan rheological model.

6. Acknowledgements: The study was supported by the Center for innovative grouting materials and Technology (CIGMAT)

7. References:

1)Lyomov S.K., Backe K.R., Skalle P., Lile O.B., Justnes H., and Sveen J., (1997), "Shrinkage of oil wells cement slurries",PETSOC,

2)Raymond W.,Nathan C., ,(2010) ,"Ultrafine Cement in Pressure Grouting", Virginia,ASCE Press

3)Vipulanandan C., Mohammed A., (2014), "Hyperbolic rheological model with shear stress limit for acrylamide polymer modified bentonite drilling muds", Journal of Petroleum Science and Engineering, 122 ,38–47