

# Viscoelastic Behavior of SBR modified Calcium Silicate Hydrate (C-S-H)

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**Abstract:** Synthetic C-S-H/Styrene Butadiene Rubber (SBR) composites were produced by mixing lime (CaO), fumed silica (SiO<sub>2</sub>), deionized water, and SBR latex. The resulting CSH/SBR composites were compacted at high pressure to mimic CSH found in hydrated cement products. To characterize the viscoelastic behavior, creep tests were carried out on the CSH/SBR composites, with varying SBR to binder using dynamic mechanical analysis (DMA). Creep compliance for various samples were determined and compared to analytical models to provide further understanding of the viscoelastic behavior of this new binder.

## 1. Synthesis of CSH/SBR composite

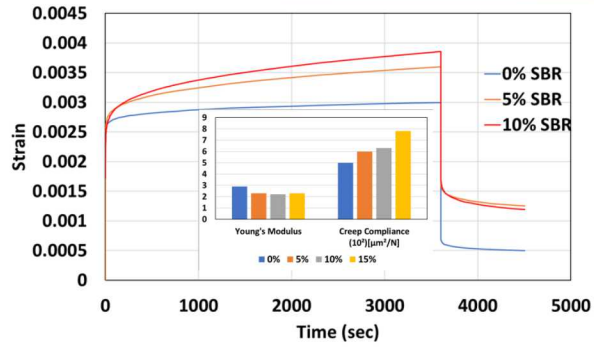


Figure showing Young's modulus generally decreasing as primary creep compliance increases

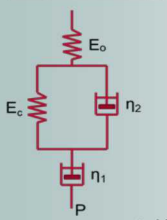
## 2. Creep Testing and Modeling



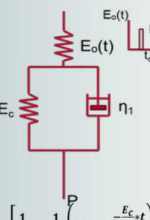
Creep testing was conducted using DMA under constant stress and ambient temperature, for the compacted specimens.

Creep modeling was conducted to determine the viscoelastic constants ( $\eta$ ) and elastic spring constants ( $E$ ) for SBR-CSH using classical creep models including the models below.  $J_n(t)$  represents the normalized creep compliance.

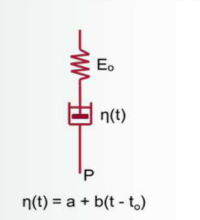
Burgers model [1]



Ross model [1]



Log model (USBR) [2]



$$J_n(t) = \frac{\sigma_0}{\varepsilon(t_0)} * \left[ \frac{1}{E_0} + \frac{1}{E_c} \left( 1 - e^{-\frac{E_c t}{\eta_2}} \right) \right]$$

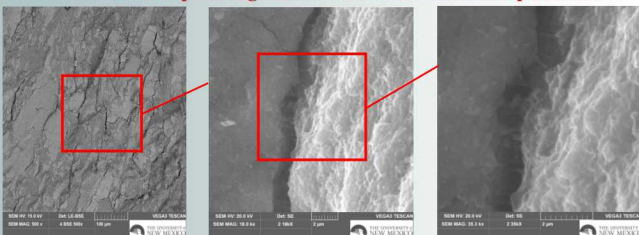
$$\eta(t) = a + b(t - t_0)$$

$$J_n(t) = \frac{\sigma_0}{\varepsilon(t_0)} * \left[ \frac{1}{E_0} + \frac{t}{\eta_1} + \frac{1}{E_c} \left( 1 - e^{-\frac{E_c t}{\eta_2}} \right) \right]$$

$$J_n(t) = \frac{\sigma_0}{\varepsilon(t_0)} * \left[ \frac{1}{E_0} + \frac{1}{E_c} \ln \left( \frac{t}{\eta_1} + 1 \right) \right]$$

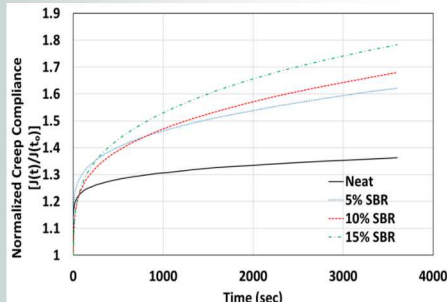
## 3. Experimental Results

15% SBR shown spanning microcracks on fractured specimens

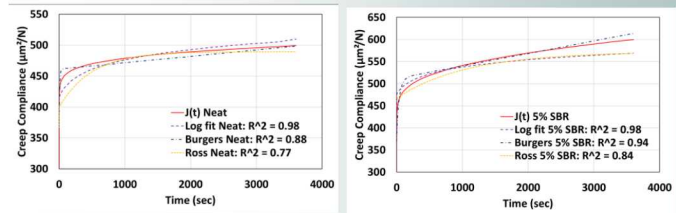


SEM micrographs showing SBR ability to improve cracking resistance of SBR-CSH composite

Right figure shows the normalized creep compliance increasing nearly 130% as the SBR content reached 15% showing the polymeric effect on the C-S-H structure. The initial elastic response also decreases as the SBR content increases

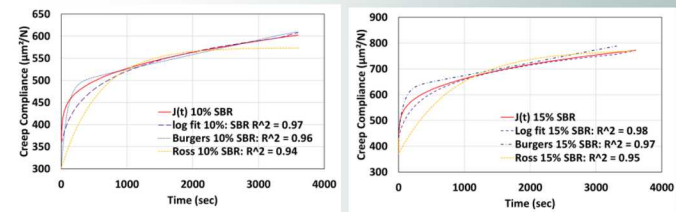


## 4. Creep Modeling



Neat (0% SBR)

5% SBR



10% SBR

15% SBR

Burgers Model	$E_0$ (Gpa)	$E_c$ (Gpa)	$\eta_1$ (GPa*s)	$\eta_2$ (GPa*s)
0% SBR	2.5	9.2	1418	1.3
5% SBR	2.3	523	7.2	5.0
10% SBR	2.2	350	4.5	5.4
15% SBR	2.3	350	5.0	8.0

## 5. Conclusions

- A New SBR modified C-S-H has been synthesized and mechanically characterized with focus to evaluate the significance of SBR on the viscoelastic behavior of C-S-H.
- Both Burgers and Ross models are able to simulate C-S-H/SBR creep behavior with reasonable accuracy. However, the two models show significant limitation in simulating creep behavior at early time

## Acknowledgments

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## References

- [1] Soliman, E. M., Kandil, U. F., & Reda Taha, M. M. (2012). The significance of carbon nanotubes on styrene butadiene rubber (SBR) and SBR modified mortar. *Materials and structures*, 45(6), 803-816.
- [2] Choi, K. K., Lissel, S. L., & Reda Taha, M. M. (2007). Rheological modelling of masonry creep. *Canadian Journal of Civil Engineering*, 34(11), 1506-1517.