Towards Understanding Cement Paste Creep: Implications from Glass Studies

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PROBLEM

Creep, the gradual structural deformation in concrete under load, can have significant impact on the durability of concrete structures. This research brief presents foundational work toward understanding the mechanics of the complex process of creep by evaluating the phenomena occurring at the nano-scale in metallic glass, a model material, to better understand what causes creep in C-S-H.

APPROACH

Molecular modeling and simulations can provide nanoscale details not achievable by purely experimental or traditional computational methods. However, an obstacle remains in that these simulations are restricted to time scales far too short to be relevant for probing the kinetics of creep. An alternative method, known as meta-dynamics sampling of transition state pathways, has recently provided new insights on deformation mechanisms of plasticity of metallic glasses. While cement paste is a more complicated structure, the understanding of metallic glasses could allow researchers to begin studying how creep occurs in the heart of cement paste, C-S-H.

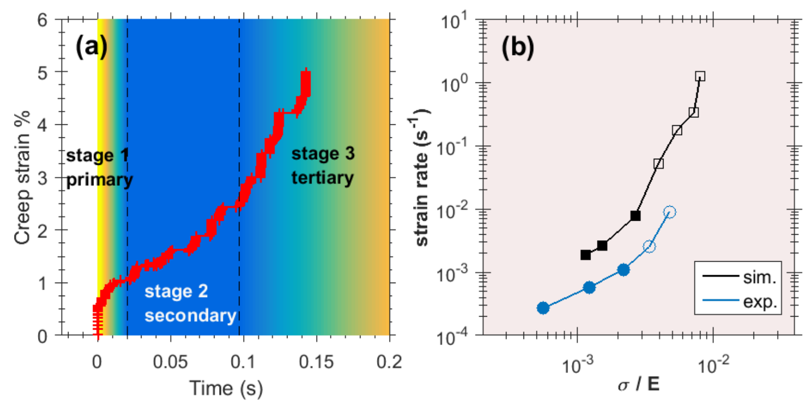

Figure 1. (a) Simulation of strain deformation in a model metallic glass at low temperature and in uniaxial tension, showing the three-stages of creep (indicated as 1, 2, 3, with strain rate determined by the linear increase in stage 2). (b) Variation of strain rate with applied stress, comparison of simulation with experiments on $Cu_{50}Zr_{50}$. Note the simulation results extend over time scales (seconds) unreachable by traditional molecular dynamics.

FINDINGS

We have identified two processes that control thermal creep: shear deformations involving only a few atoms and the formation and growth of a more extended structural defect known as a shear band. Knowing how these processes are connected, one can explain the variation of strain in a material undergoing creep damage. Creep generally occurs in three stages (see Fig. 1(a)): 1) an initial increase in strain logarithmically in time (transient or primary creep); 2) a secondary stage of linear increase (steady-state creep) which continues until; 3) an accelerated rate sets in (tertiary creep), indicating the onset of structural failure. In demonstrating experimental validation of simulation, Fig. 1(b) indicates the existence of two regimes of stress effects on creep rate, thermal activation at low stress, and stress activation above a characteristic threshold. This is a general behavior that should also apply to cement paste.

WHY DOES THIS RESEARCH MATTER?

- Creep is a technologically important phenomenon of which fundamental understanding is lacking.
- This research brief presents new insights into stress sensitivity of creep deformation in a metallic glass (a model material) with implications that may be relevant to C-S-H.

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