# Role of Particle Shape in Fabric Evolution during Compressive Creep Failure of Concrete

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## 1. INTRODUCTION & OBJECTIVE

Concrete creep has long been recognized as an essential phenomenon effecting the serviceability and safety of structures. However, conventional studies of creep are limited to low to medium stress levels ($\leq 0.7f_c$), often neglecting the higher stress regimes when tertiary creep and eventually failure of concrete occur[1]. Moreover, due to computational constraints for long-term analysis, mesoscale analysis of creep in this zone is further challenging. In mesoscale analysis of concrete using the discrete element method (DEM), concrete is modelled as a heterogeneous material. The concept of "fabric" is used to quantify the amount of heterogeneity present within the material[2]. Primarily, fabric is a tensor refers to the spatial arrangement and orientation of constituent particles and cracks. In contrast to macroscopic mechanical properties, fabric provides a mesoscale perspective, capturing how the local interactions between particles evolve under external loading and over time. Particle assembly constituted by round particles tends to exhibit uniform stress transfer and more isotropic arrangements, whereas angular particles induce stress concentrations and more anisotropic contact evolutions[3]. Consequently, the role of particle geometry on fabric evolution is indispensable for elucidating the mesoscale origins of the macroscopic creep phenomenon. In this study, a DEM framework is employed to investigate the evolution of fabric with different stages of creep at stress level $0.8f_c$ and $0.9f_c$. Particular emphasis is placed on the evolution and localization of cracks and the effect of particle morphology at these stress levels. The insights gained aim to advance the understanding of creep mechanisms at high stress limits, while simultaneously boosting the material's safety and serviceability for complex structures.

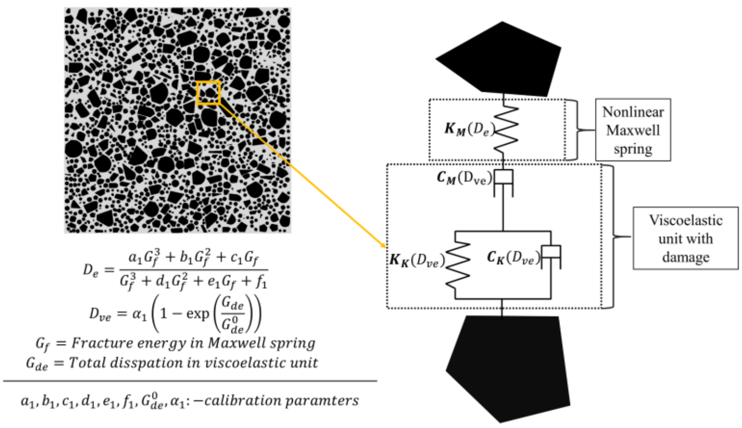


Figure 1. Meso scale constitutive model to simulate nonlinear creep of concrete

## 2. METHODS OF ANALYSIS

In the DEM analysis of concrete, the constituent particles are explicitly modelled, and the interaction between two particles, which resembles the cement paste, is not modelled separately.

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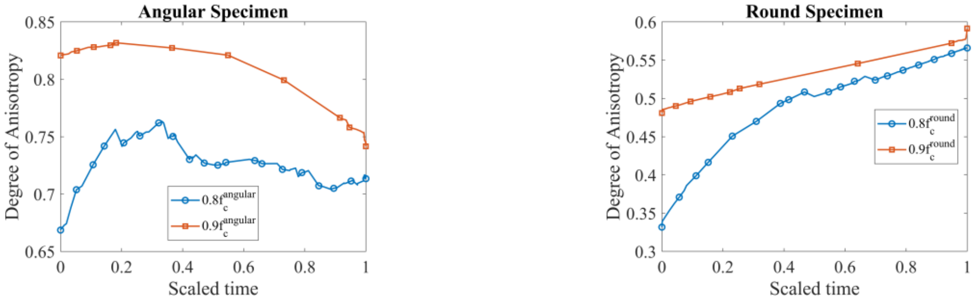
Instead, the interactions are modelled by using spring dashpot system. In this study, nonlinear Burger's model with damage is introduced to represent the aggregate interactions (Figure 1). Generally, in traditional DEM, explicit time integration is used and the stable time increment is extremely small (on the order of $10^{-8}$)for irregular particle geometries. The modified adaptive dynamic relaxation algorithm proposed by Mukherjee and Deb[4] is implemented to address this bottleneck.

## 3. RESULTS

The evolution of the degree of fabric anisotropy($J_2^*$), which is determined from the second-order deviatoric tensor computed from the Fabric tensor($\boldsymbol{\mathcal{N}}$), is presented in Figure 2. Mathematically, the fabric tensor $\mathcal{N}_{ij}$ is defined as the average of the outer products of the contact normal vectors over all particle contacts. From Figure 2, it is evident that for both the specimens, $J_2^*$ is less at $0.8f_c$, compared to the $0.9f_c$, indicating that the lesser localization of cracks happens at $0.8f_c$.




(a) (b)

Figure 2. Evolution of the degree of anisotropy for (a) Angular and (b) Round specimens at stress levels of 80% and 90% of their respective ultimate stress levels.

## 4. CONCLUSIONS

This study highlights that fabric evolution is a primary drivers of creep response and failure at high stress levels, rather than only the damage magnitude. At higher compressive load ($\geq 0.7f_c$), specimens composed of angular particles develop a higher degree of fabric anisotropy, meaning more distributed cracks and lesser localization, which can be attributed to the greater axial failure strain. However, round particle assemblies show a lesser degree of anisotropy, indicating more damage localization, and therefore fail early compared to the angular particle assemblies. The degree of anisotropy emerges as a state variable that tracks the amount of damage and the formation and distribution of cracks within the particle assemblies.

## 5. REFERENCE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