Modeling fracture in quasi-brittle materials under high frequency loading using a multi-scale method

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Introduction

Macroscopic behavior of quasi-brittle materials is determined by their heterogeneous microstructure. Initiation and propagation of cracks are controlled by the randomness of the material and occur at different length scales (figure 1). Multi-scale approaches provide methodologies to obtain the mechanical behavior of a heterogeneous material from a local scale response. The present project deals with developing an objective multi-scale method to model cracking in heterogeneous materials under high frequency loading conditions.

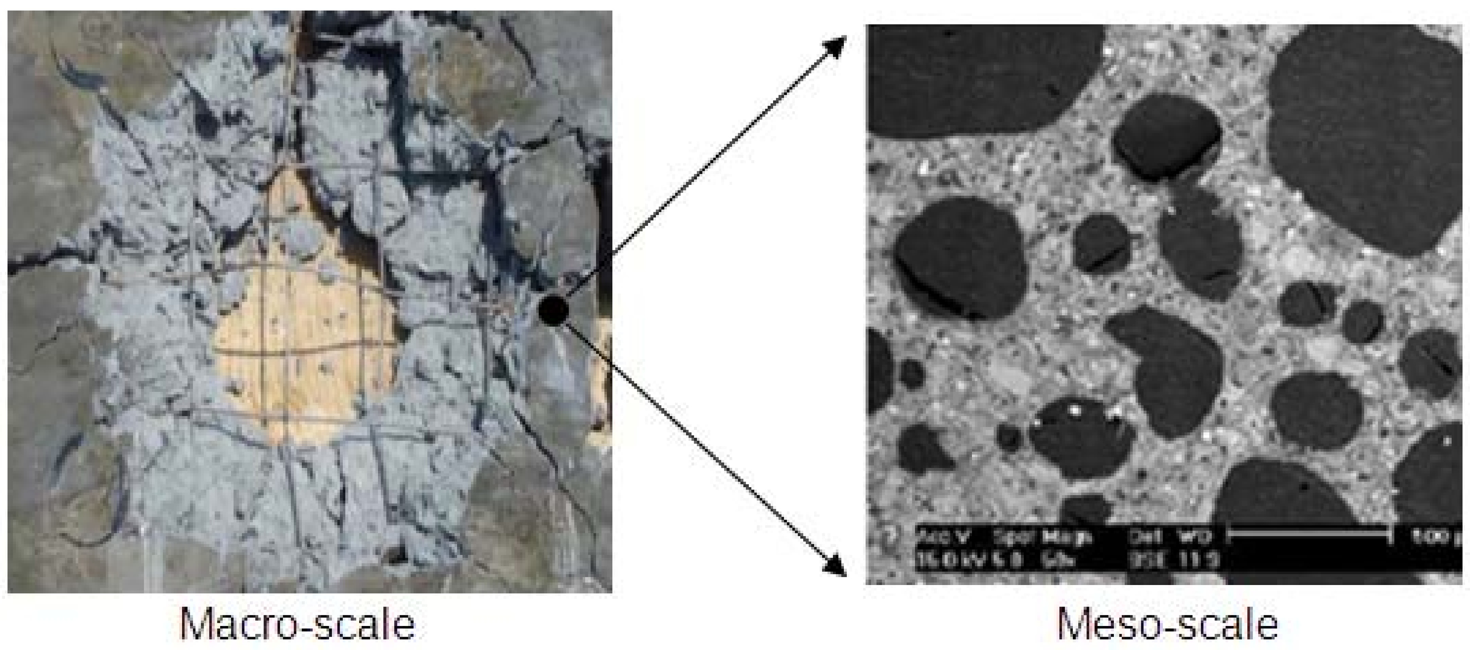

Figure 1: Heterogeneous materials

Multi-scale model

A standard computational homogenization scheme is used until strain localization occurs in the material. When localization occurs in the RVE associated to a certain macro material point, a crack initiates and the cohesive law for the crack is determined using a discontinuous homogenization scheme (figure 2). When the macroscopic wave length is significantly larger than the meso-scale characteristic length, the meso-scale problem can be solved as a quasi-static problem [1]. In figure 3 objective results are shown. However, when the macroscopic wave length becomes comparable to the meso-scale characteristic length, meso-scale inertia forces lead to **dispersion effects** which are not captured in the model.

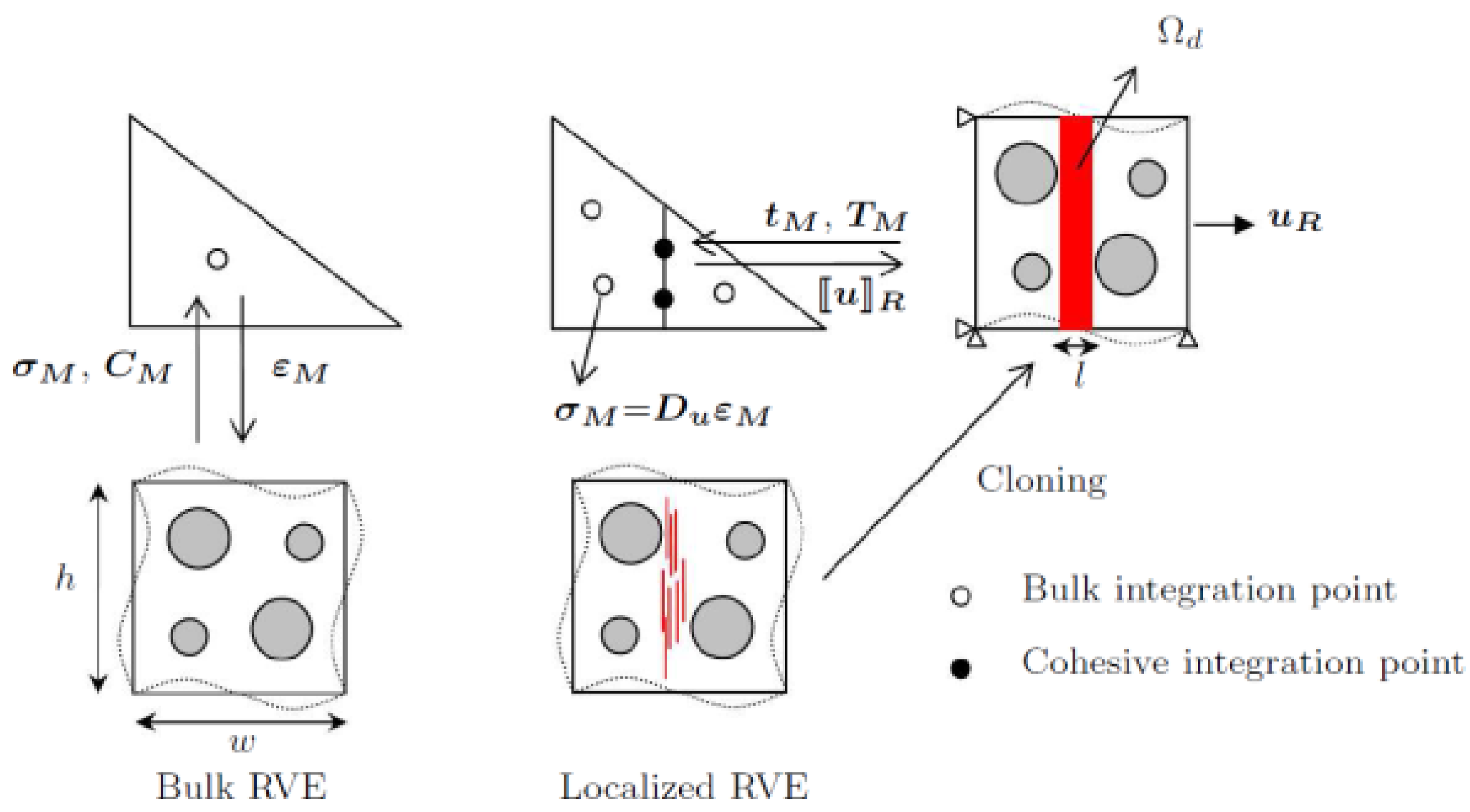

Figure 2: Multi-scale scheme

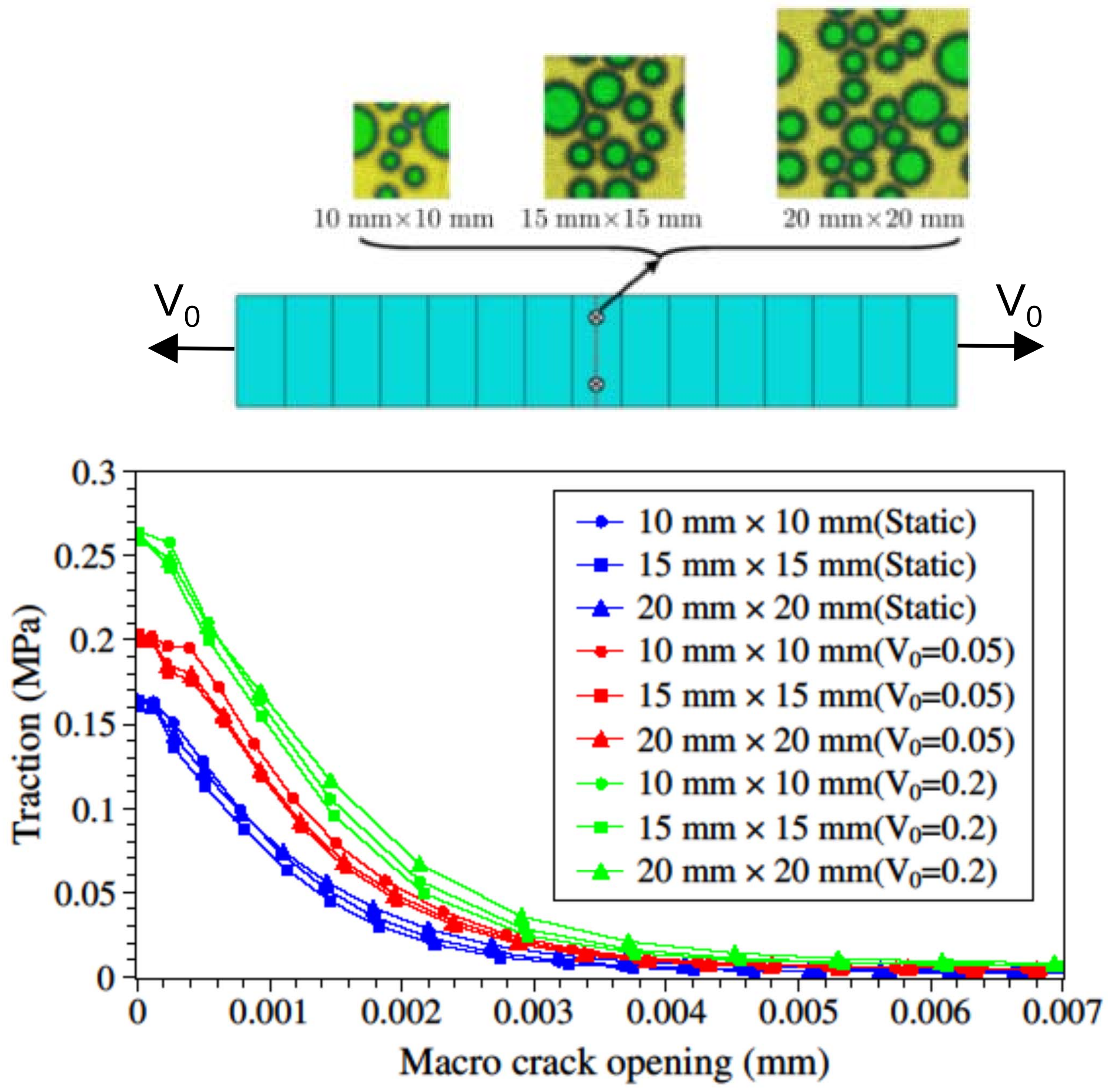

Figure 3: Traction-separation curves for different RVE size and different loading rates

Dispersion effects

Dispersion effects can be taken into account through a so-called dispersion tensor which depends on the meso-scale model heterogeneity:

$$D_{ijkl} = \frac{\rho_c}{|\Omega|} \int_{\Omega} h_s^{ij} h_s^{kl} d\Omega \qquad (1)$$

Where h_s^{ij} is a periodic tensor which depends on the material properties of the meso-scale model and can be obtained by solving a **quasi-dynamic** problem at the meso-scale. The dispersion tensor appears in the macro-scale formulation as an additional inertia force. Dispersion effects caused by meso-scale inertia forces are shown in figure 4.

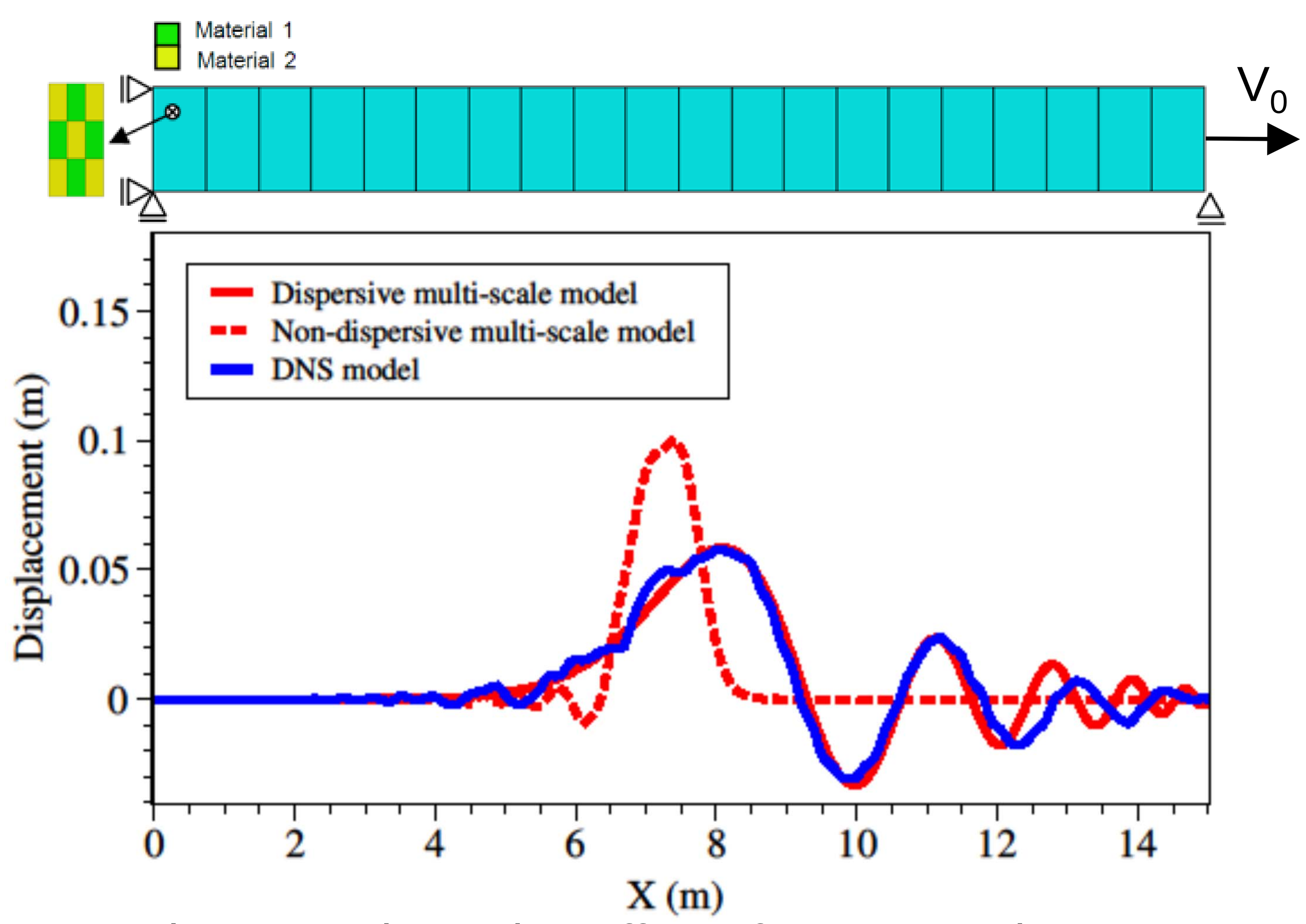

Figure 4: Dispersion effects for propagating wave

References

[1] A. Karamnejad, V. P. Nguyen and L. J. Sluys, A multi-scale rate dependent crack model for quasi-brittle heterogeneous materials, EFM, 104, 96-113, 2013.