Relationship between size and strain rate effects on strength of quasi-brittle materials

Chengzhi Qi, Hongsen Wang

Beijing Future Urban Design High-Tech Innovation Center, Beijing University of Civil Engineering and Architecture, Beijing, 100044, China. E-Mail: qichengzhi65@163.com

For type 1 size effect, based on a relaxation model, the relationship between spatial and temporal properties of deformation and fracture of quasi-brittle materials is established, the essence of which lies in the finiteness of crack propagation speed and the complex internal structural hierarchy. There exists one-to-one correlation between characteristic length scale and characteristic strain rate, i.e., in order to fracture a sample of size L or activate structural elements of size L, definite strain rate $\dot{\varepsilon}$ must be applied, below which a sample of size L would not fracture or structural elements of size L would not be activated. From the viewpoint of structural hierarchy, the size effect may be considered as the realization of the structural surface strength of smaller scale structural elements with the decrease of the sample size. The essence of strain rate effect is that because of the finiteness of crack propagation speed, the increase of strain rate activates the deformation and fracture process of smaller scale elements before the complete fracture of the sample. The dynamic strength of material is the realization of size effect on strength at the activated smaller scale level of solid. Based on one-to-one correlation between characteristic scale level and characteristic strain rate, size effect equation is transformed into strain rate effect equation.

For type 2 size effect, based on the fracture energy of cracked quasi-brittle materials, the relationship between the energy release rate and the crack propagation velocity of the crack tip under plane strain condition is deduced according to the dynamic stress and strain fields of the crack tip. Furthermore, it is assumed that the variation of strain energy is mainly caused by the energy consumption of the fracture process zone (FPZ), and the variation of the area of the crack fracture process zone (FPZ) with the crack velocity is determined. Combining the Hu & Duan's boundary effect formulas, the relationship between propagation toughness and crack velocity of cracked quasi-brittle materials is deduced. Numerical results show that the area of the fracture process zone (FPZ) increases with the increase of the crack propagation velocity, and so is the energy release rate of the crack tip, therefore the fracture toughness of the material increases with the increase of crack propagation velocity..

This investigation will give better understanding of dynamic phenomena of deformation and fracture of quasi-brittle materials, including concrete, rocks etc.