Prof. Kedar Kirane's Research Interest

Prof. Kedar Kirane's research interest primarily lies in the development of computational and analytical models for complex phenomena, such as damage, fracture and scaling in heterogeneous materials such as fiber reinforced composites, concrete and rocks. He is also interested in conducting suitable experiments, crucial for calibration and verification of the models. The phenomena he works on, are fundamentally non-linear and occurring on multiple spatial and temporal scales and understanding them is critical to a wide variety of engineering applications.

One of the key focus of Prof. Kirane's research is the quasi-brittleness of the failure behavior in these materials, and the resulting scaling. Unlike metals or fine grained ceramics, quasi-brittle materials fail by the formation and propagation of a finite sized fracture process zone (FPZ) whose size is not negligible compared to the structure size. This leads to a non-self-similar scaling in the structural strength which is governed by a material characteristic length scale and must be accounted for in structural design criterion. This aspect is missed by traditional stress or strain based failure criterion and therefore do not apply to these heterogeneous materials.

The quasi-brittleness of fracturing and the resulting scaling must be reproduced objectively by any realistic constitutive model for failure of such materials. To this end, one of the important past research contributions of Prof. Kirane is the development of a multi-scale constitutive model – the "microplane triad model".

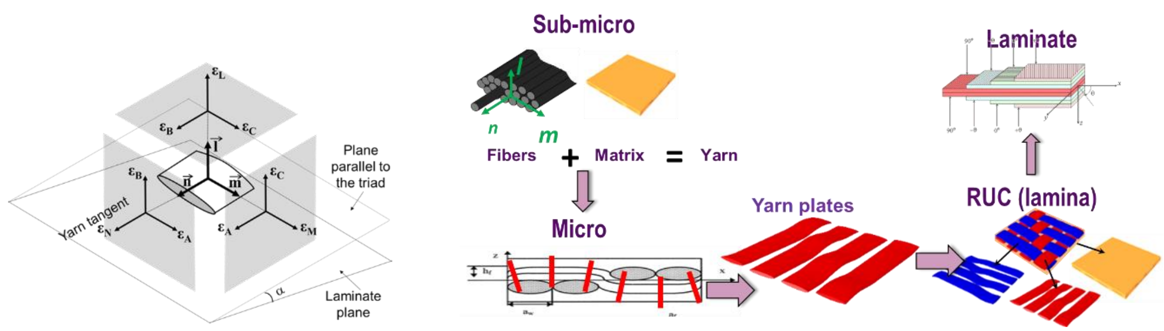

Fig. 1 Schematic describing the basic idea of the microplane triad model

In this model, the mechanical damage behavior on the meso-scale is described by a finite number of microplane triads of various orientations, the microplanes being imagined planes within the material microstructure. Within each triad, the micro-scale damage behavior is described at constituent level and is correlated to the macro-scale fracture energy in order to capture the quasi-brittleness. The material characteristic length is introduced through the framework of the crack band or smeared crack theory. It is shown found that the model can accurately predict the fracturing behavior, including the correct energy dissipation, failure pattern and most importantly the size effects. The model is promising and extensible to many modern composite materials, including braided, hybrid and multi-functional, which are of much current interest.

For composites, a challenge in applying these principles is the direct measurement of the fracture energy - due to their extreme snap-back behavior. To overcome this, Prof. Kirane worked on an innovative testing protocol - called the size effect method, during his doctoral work. It involves strength testing of geometrically scaled specimen, subsequently inferring the fracture energy by regression of quasibrittle strength scaling laws. This is a very simple but effective method to characterize the fracture behavior of any quasi-brittle material, including various advanced composites.

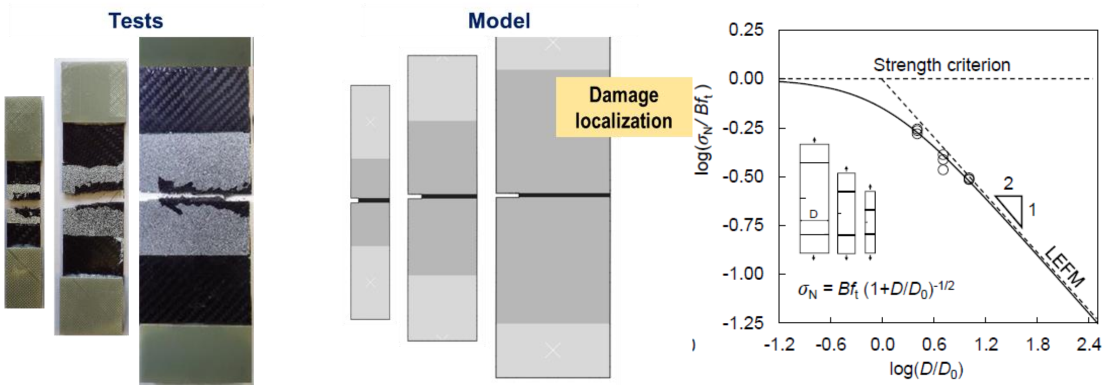

Fig. 2. Application of the size effect testing method to fiber reinforced composites and predictions by the microplane triad model via the smeared crack approach

The quasibrittle aspect is important in other failure modes too – e.g. fatigue. While the scaling aspect and its relation to failure is well understood for monotonic loading, this is not true for cyclic loading. Some of Prof. Kirane's doctoral work also was aimed at addressing this problem for concrete. He developed a novel size adjusted Paris law to explain the structural size scaling in fatigue crack growth rates. He also showed that a suitably calibrated fatigue damage model can automatically reproduce this scaling. This aspect definitely requires deeper study and the findings will help form a sound scientific basis for applying lab based data to real world, larger structures. And they could have significant implications on the fatigue design and reliability of aircraft components, naval structures, wind turbines, etc.

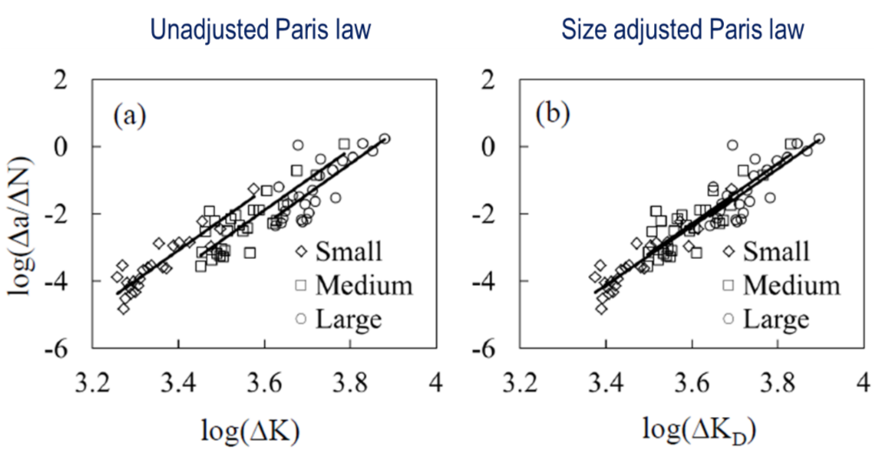

Fig. 3 Scaling in Paris law as a consequence of quasi-brittleness on fatigue behavior