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A novel multi-level model for quasi-brittle cracking analysis with complex microstructure

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Numerical model of global level

- **Basic unknowns defined on the boundary of material particle**

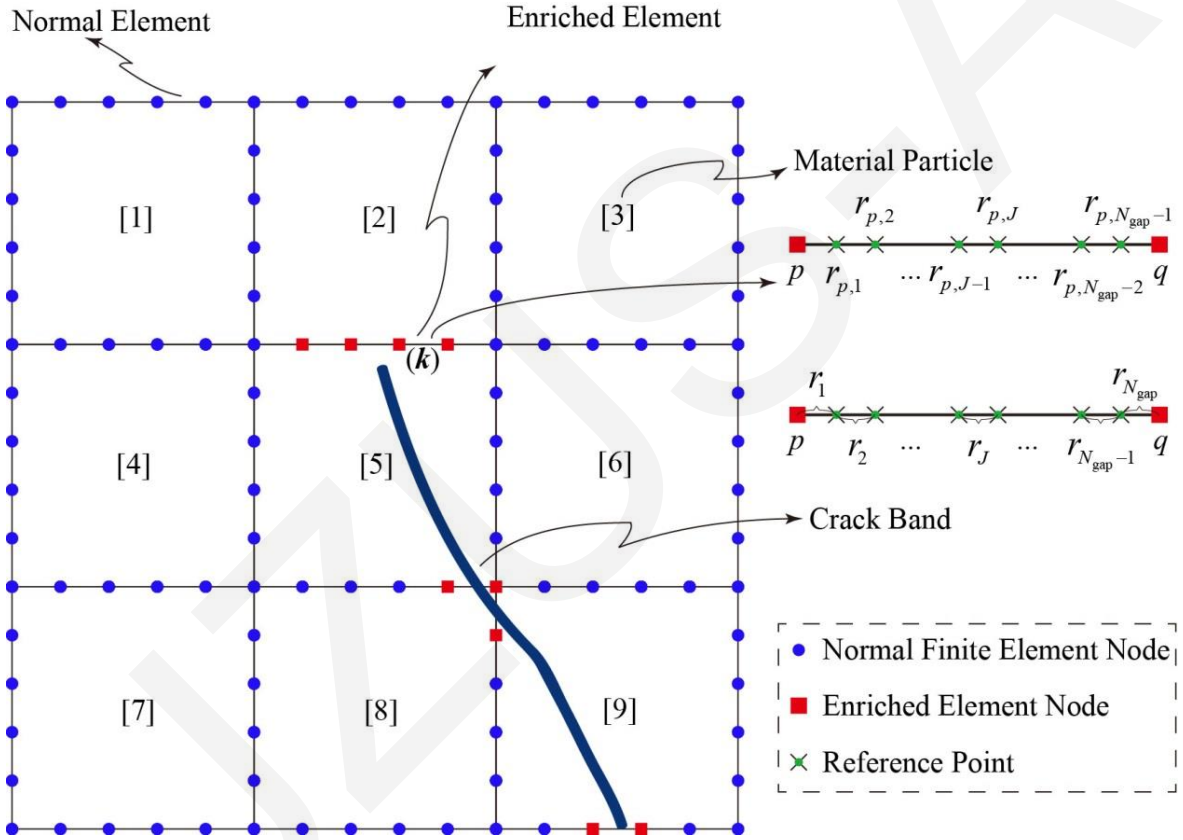

Fig. 1 Discretization of material particles' boundaries.

Multi-level model

- **Information transmission from RVE to material particle**

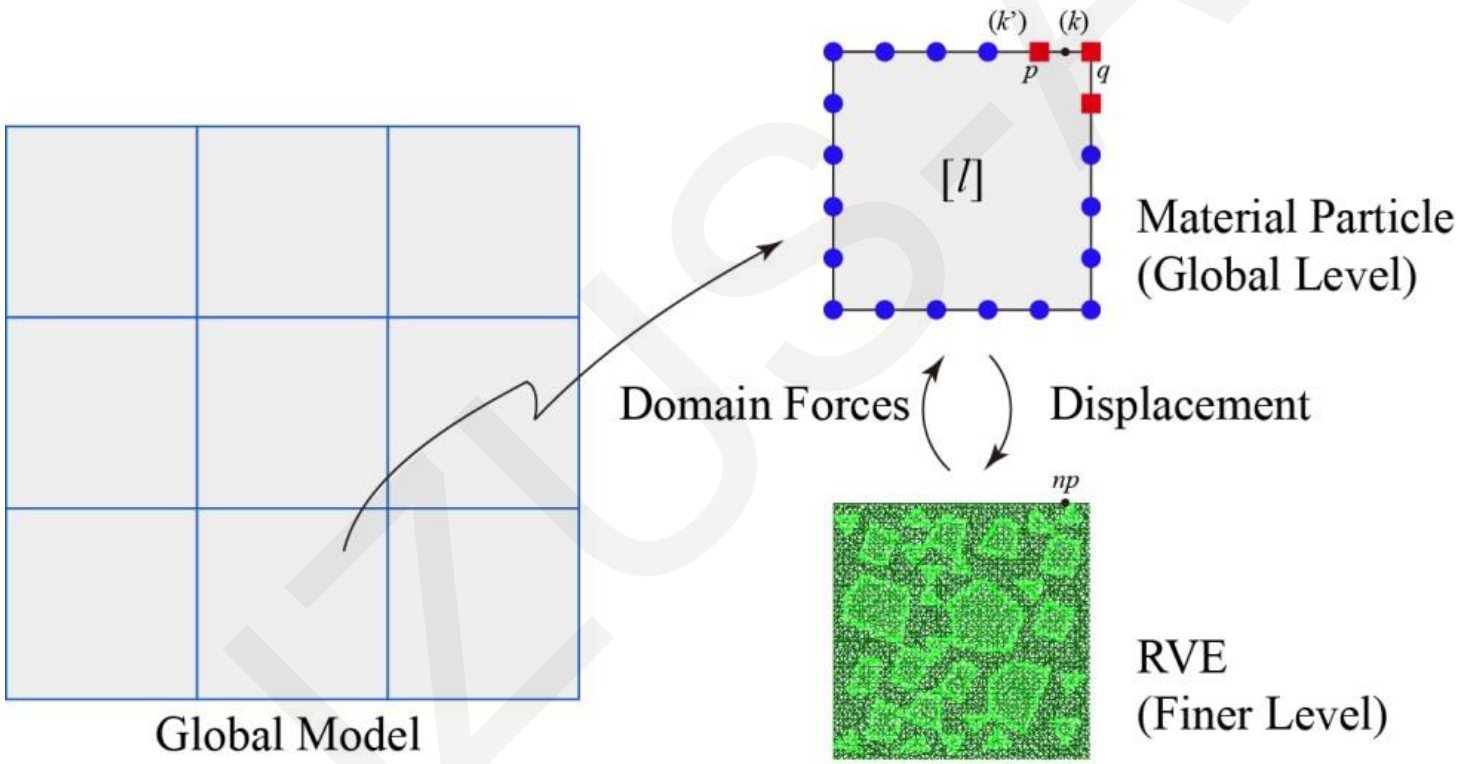

Fig. 2 Multi-level information transmission model.

Numerical results

Comparison between MLPU and reference solutions

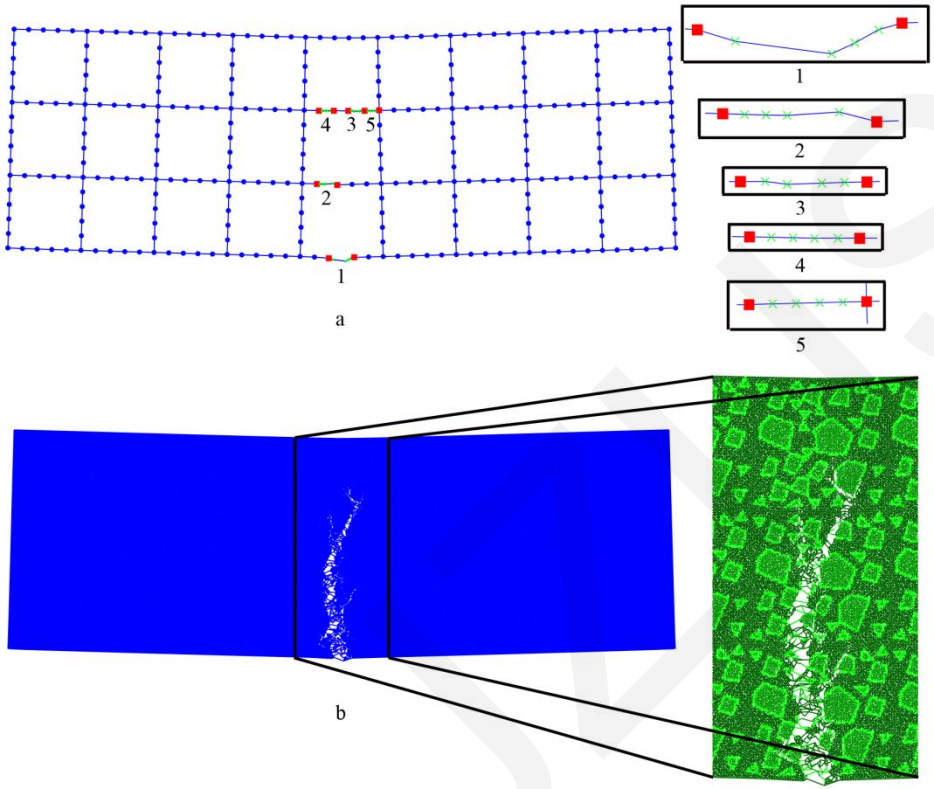

Fig. 3 Deformation of beam specimen: (a) MLPU and (b) full microscopic model.

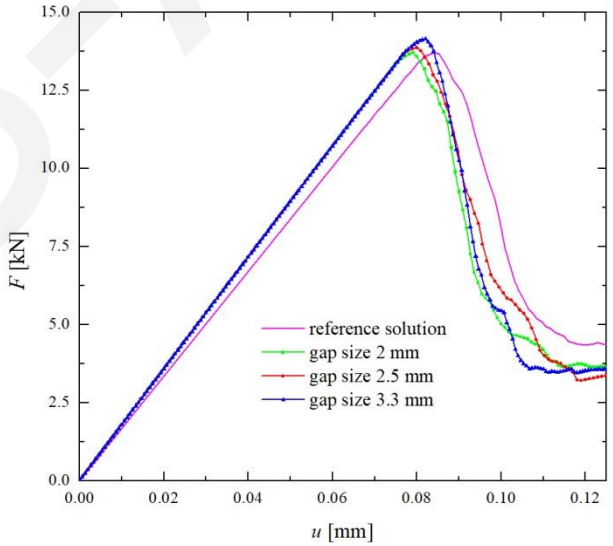

Fig. 4 Load versus displacement curves for beam model: MLPU and reference solution.

Numerical results

- **Comparison between MLPU and reference solutions**

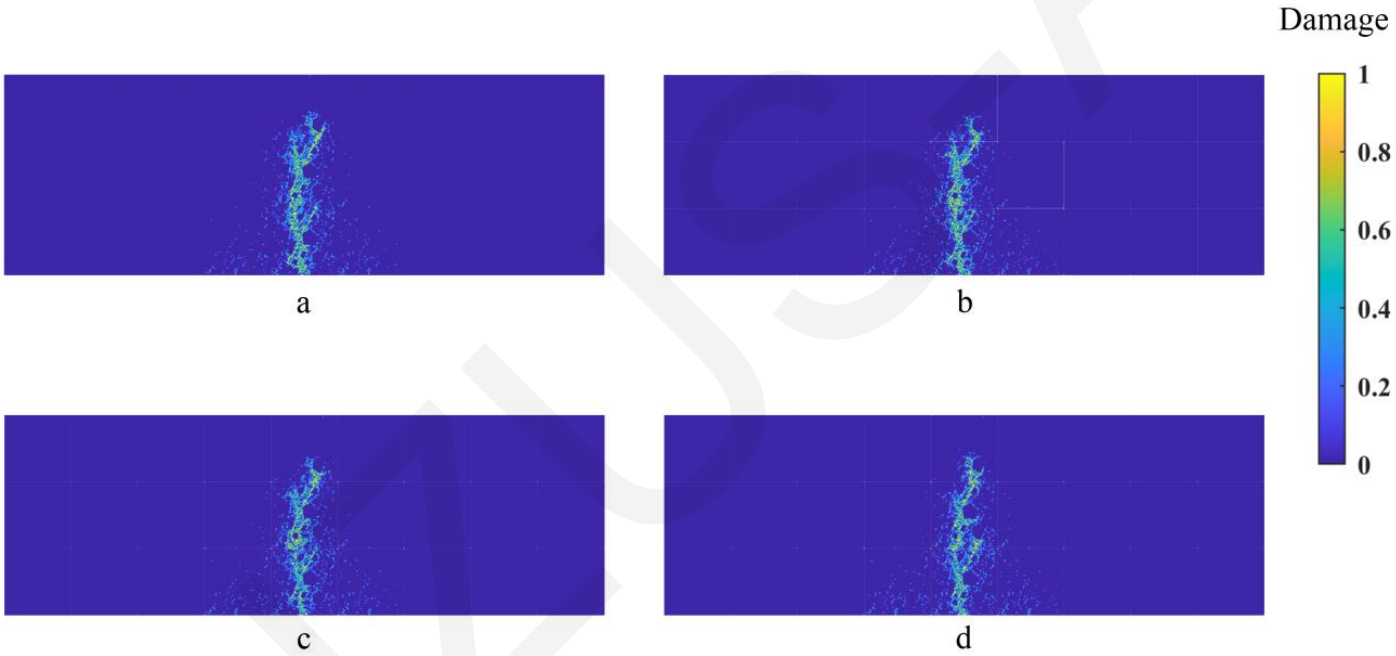

Fig. 5 Damage distribution of failure beam specimen: (a) reference solution; (b) MLPU, gap size 2 mm; (c) MLPU, gap size 2.5 mm; (d) MLPU, gap size 3.3 mm (inactivated RVEs in (b), (c) and (d) are added to paint the entire specimen for comparison).

Numerical results

Comparison between MLPU and reference solutions

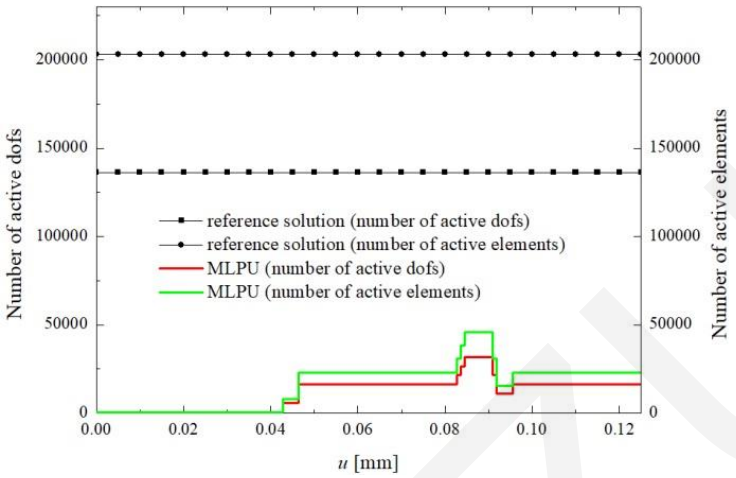

Fig. 6 Number of active degrees of freedom and elements in beam specimen during analysis: MLPU and reference solution.

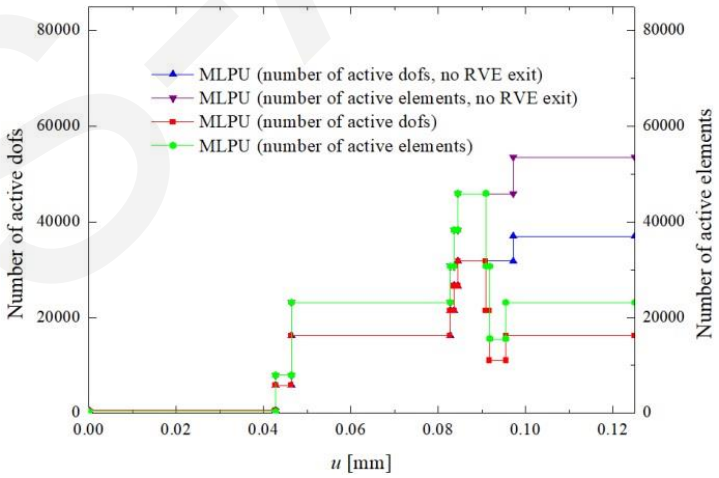

Fig. 7 Number of active degrees of freedom and elements in beam specimen during analysis: MLPU with RVE exit and no RVE exit.

Numerical results

Comparison between MLPU and reference solutions

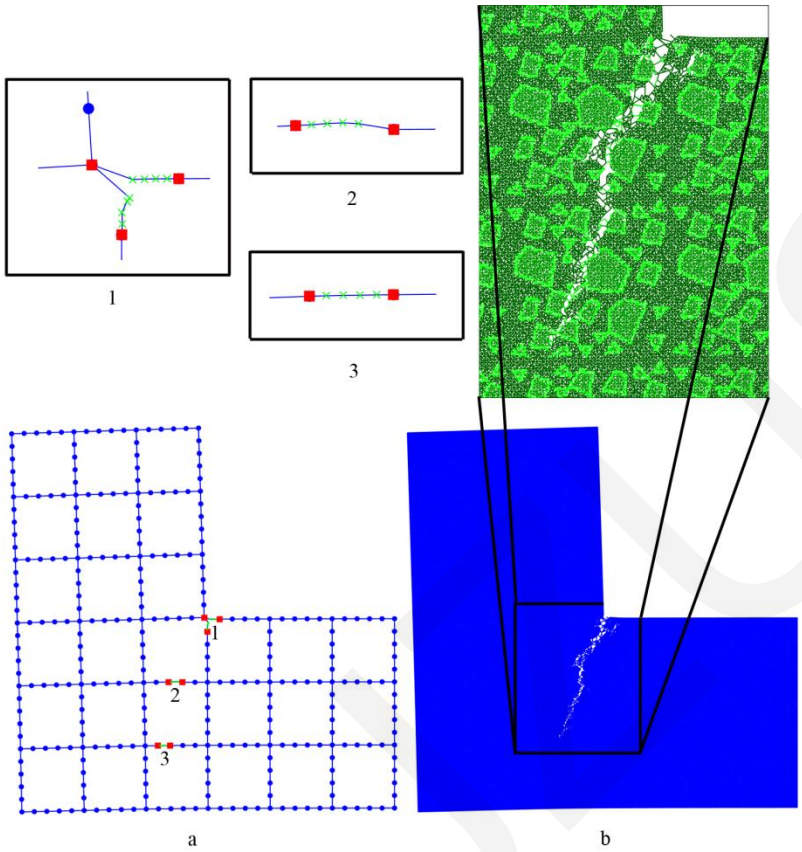

Fig. 8 Deformation of L-shaped specimen: (a) MLPU and (b) reference solution.

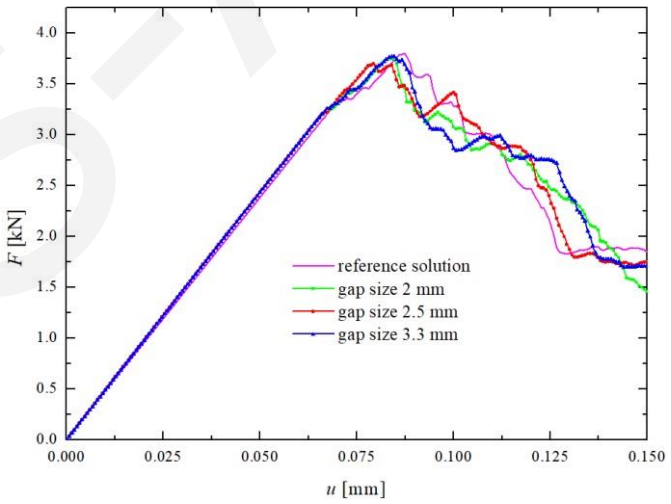

Fig. 9 Load versus displacement curves for L-shaped model: MLPU and reference solution.

Numerical results

Comparison between MLPU and reference solutions

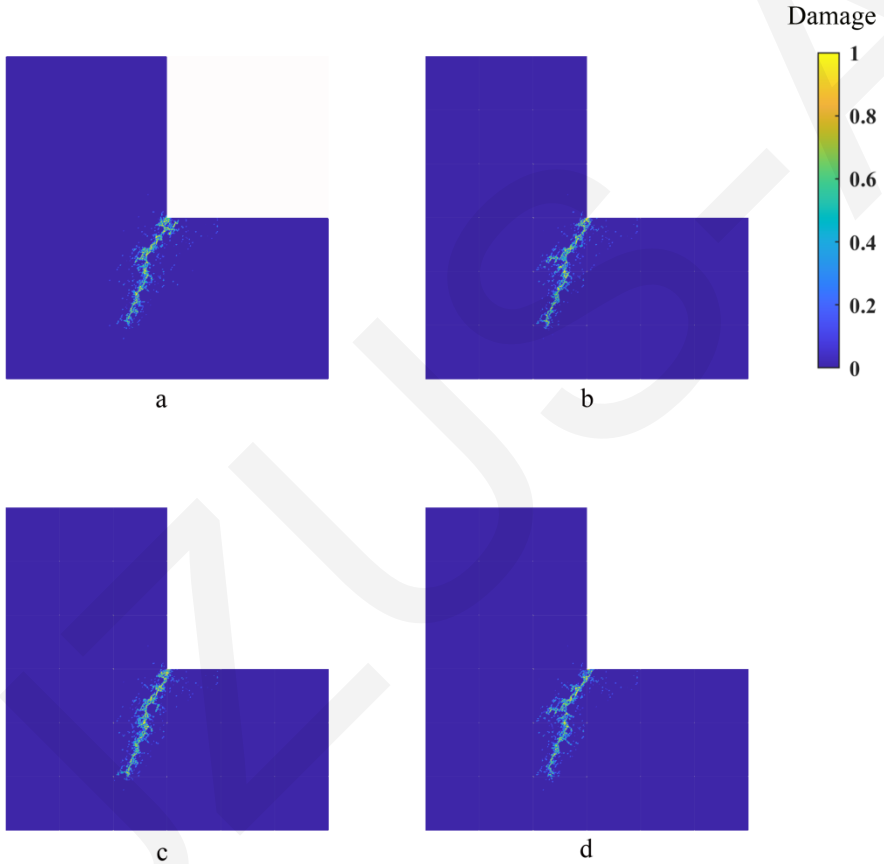

Fig. 10 Damage distribution of L-shaped specimen: (a) reference model; (b) MLPU, gap size 2 mm; (c) MLPU, gap size 2.5 mm; (d) MLPU, gap size 3.3 mm (inactivated RVEs in (b), (c) and (d) are added to paint the entire specimen for comparison).

Numerical results

Comparison between MLPU and reference solutions

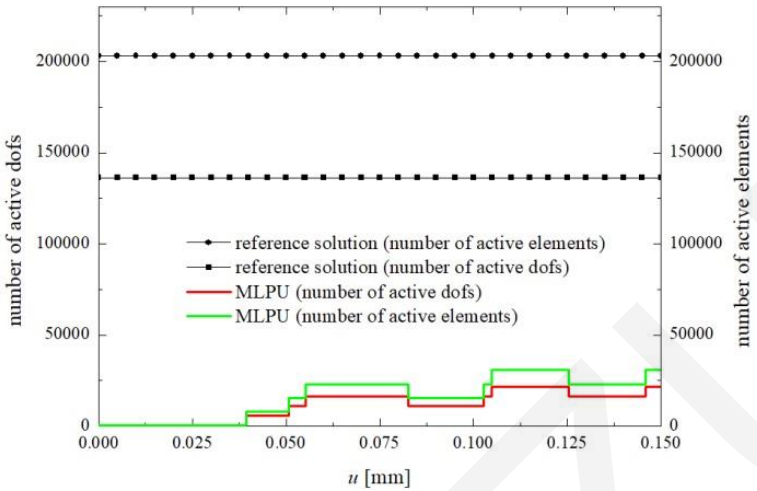

Fig. 11 Number of active degrees of freedom and elements in L-shaped specimen during analysis: MLPU and reference solution.

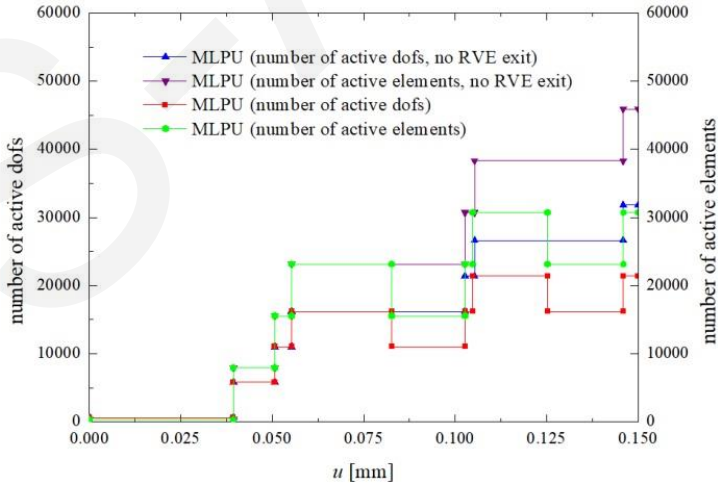

Fig. 12 Number of active degrees of freedom and elements in L-shaped specimen during analysis: MLPU with RVE exit and no RVE exit.

Conclusions

- A novel multi-level model for quasi-brittle cracking analysis is established.
- A series of enrichment functions with continuous steps are developed.
- The unloaded RVEs can exit the computation to save computational effort.
- The concrete fracture experiment and DIC test are done to verify the model.
- The degrees of freedom of the entire model keep a stable low level during analysis.
- This is a totally non-re-meshing framework that describes the crack pattern accurately.