3D Fracture Analysis Of Viscoelastic Pavement Materials Using The Generalized Finite Element Method (GFEM)

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Motivation and Research Question

Asphalt pavements are among the key transportation infrastructure which state and local department of transportation agencies spare a significant part of their budget to build and maintain. Despite its marked importance, the question on how to robustly design pavements has not yet been addressed. Pavement structures usually experience various cracking defects [1]. These cracks are typically arbitrarily aligned and occur at different locations within the structure which make their modeling challenging.

Figure 1. (a) Top-bottom cracking resulting from high axle/tire pressure on pavement surface (b) block cracking due to shrinkage of asphalt concrete from daily temperature cycling

Research Methodology

A Generalized Finite Element Method (GFEM) based tool called ISET was used to study cracking in asphalt pavements. The GFEM effectively assign localized special enrichments functions to account for known features such as discontinuities and defects in structures [2]. See figure 2.

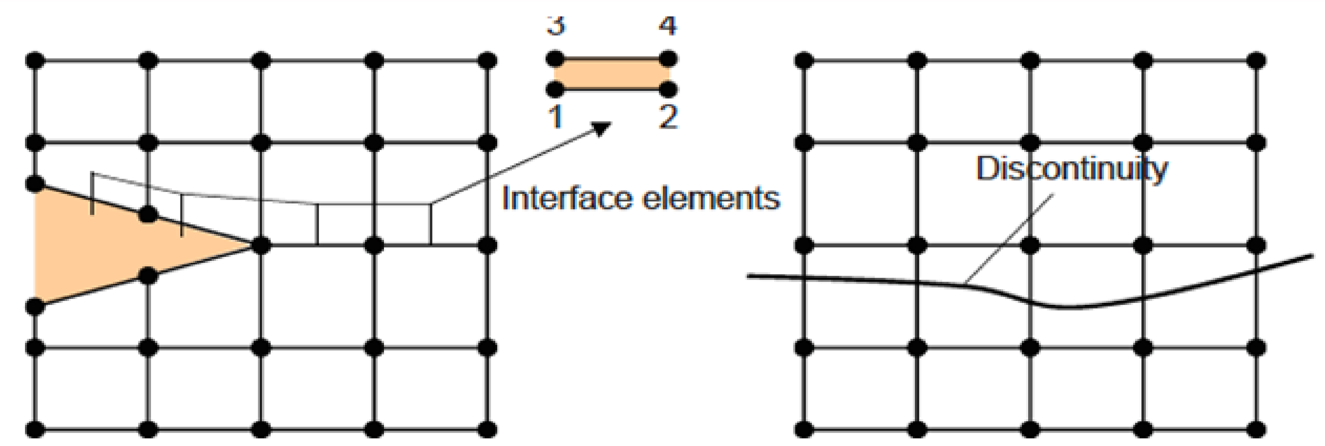

Figure 2. A schematic of finite element mesh with a discontinuity represented by (a) interface elements (b) without any special elements at the interelement boundaries (Ozer, 2011)

Specimen Modeling and Results

The GFEM tool ISET was used to extract Stress intensity factors (SIFs) in a SCB specimen (shown in fig. 3a) modeled in the 3-D setting. Step and branch function enrichments were assigned over the crack surface. The obtained ISET results compared closely with the reference results presented by Lim et. al [3] as shown in figure 4.

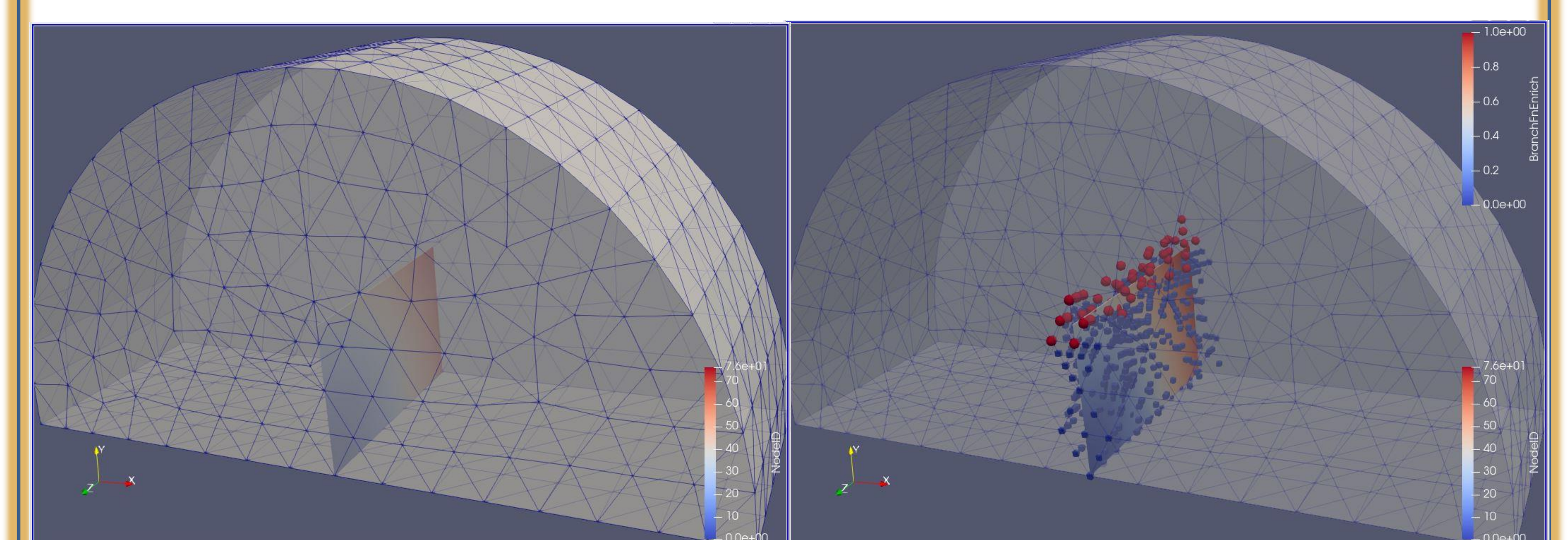

Figure 3. (a) The SCB problem with inserted crack surface (b) enrichment glyphs at the crack tip and around the crack surface

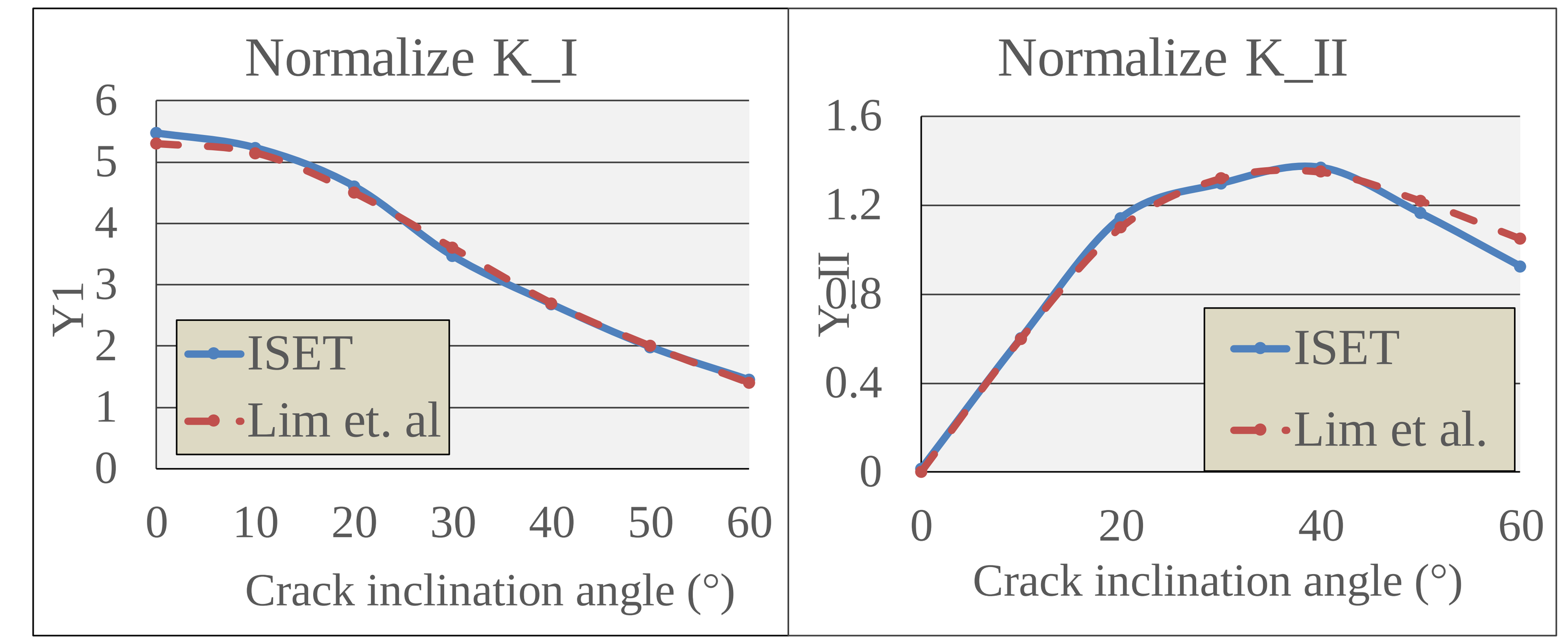

Figure 4. Extracted SIFs compares closely with results presented by Lim et al

Conclusion

The GFEM approach provided the computational efficiency to analyze a 3-D cracking experimental problem. There was no need to prepare a new mesh for every crack case simulated. Therefore, we were able to derive the results in a very computationally efficient and rapid way.

Future Work

The simulation will be extended to a viscoelastic material. SIF which is linear elastic fracture mechanics parameter will not work in the viscoelastic case. Therefore, other parameters of fracture such as energy release rate or J-integral need to be computed. Those viscoelastic fracture parameters will also be needed to predict cracking in actual pavements under realistic loading and climate conditions.

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References

1. S. Buchanan, "Balanced Mix Design," in APAM Asphalt Paving Conference, Michigan, 2017.
2. H. Ozer, Development of domain integral and GFEM for three 3-D analysis of near-surface cracking in flexible pavements, (Doctoral dissertation, University of Illinois at Urbana-Champaign), 2011.
3. I. Lim, I. Johnston and S. Choi, "Stress Intensity Factors For Semi-Circular Specimens Under Three-Point Bending," Engineering Fracture Mechanics, vol. 44, pp. 363-382, 1993.

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