Neptune Research Inc. (NRI)
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TECH MEMO

Tech Memo #: 19-0101
To: NRI and Clients
Subject: *Scar-Guard Strength, Stiffness, and Fracture Toughness*
Issue Date: Jan. 9, 2019

INTRODUCTION:

The performance of Scar-Guard® (SCG) has shown to be more reliable than field joint coatings (FJC) alone for the protection of field joints and FJCs based on results observed in numerous HDD (horizontal directional drilling), thrust bore, and micro-tunnel projects over the last decade. Abrasion, impact, and gouge testing commonly found on FJC datasheets have been performed on Scar-Guard. Lab test results have shown little to no noticeable difference between Scar-Guard and FJC properties, even though field performance results are vastly different. The method of failure for FJC exhibits characteristics to that of shearing, tearing, and crack opening (examples in Figure 1) which are fundamentally related to the material property known as the critical stress intensity factor, K_c, or fracture toughness. To confirm this theory, NRI has conducted multiple tests to validate the properties for comparison purposes.

Figure 1 - Shearing, tearing, and opening failures

NRI University has performed fracture toughness testing for two commercially available, liquid, field-applied epoxy FJC's as well as Scar-Guard XL, Scar-Guard, and Scar-Guard E (various system options within the Scar-Guard family of products). An overview of results along with further explanations of strength, stiffness and fracture toughness is provided below. The figures show the regions in which composites such as Scar-Guard and polymer FJC's typically perform.

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COMMENTS:

Strength

- How strong a material is, measured in psi (Pa).
- Figure 2 shows material strengths from weakest to strongest – bottom to top
- Glass Composite – 80,000 psi
- Epoxy Coating – 10,000 psi

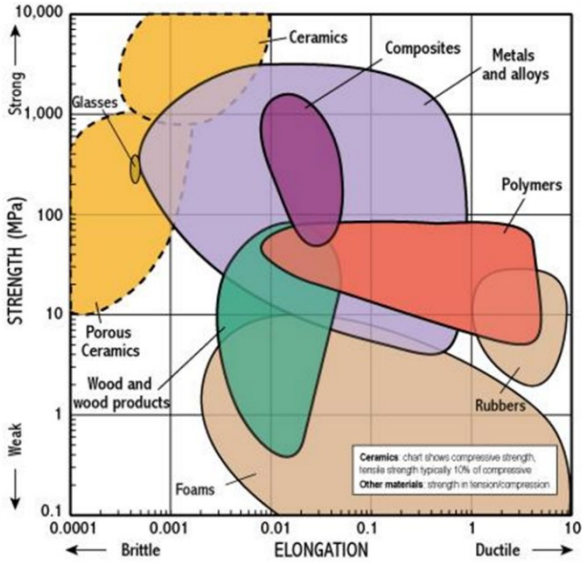

Figure 2 - Strength of Materials

Stiffness

- A material's resistance to deformation, also measured in psi (Pa).
- Figure 3 shows material stiffnesses from highest to lowest, bottom to top
- Composite 4,000,000 psi
- Epoxy Coating 250,000 psi

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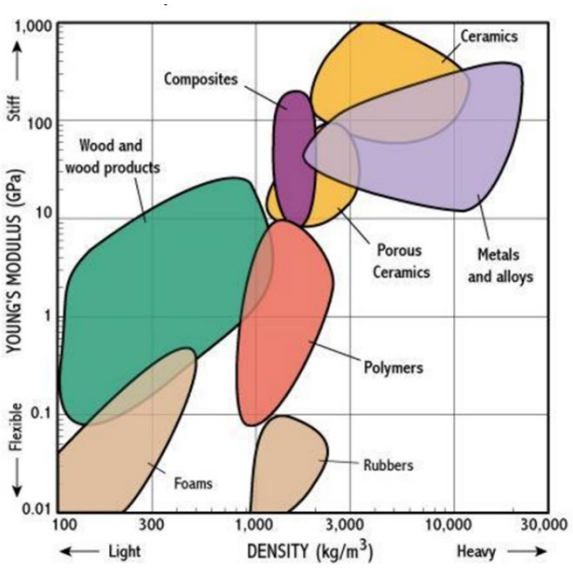

Figure 3 - Stiffness of materials

Fracture Toughness

- Fracture toughness measures the ability of a material to resist fracture.
- Figure 4 shows material toughness from lowest to highest, left to right
- Low toughness is considered brittle, high toughness is considered ductile

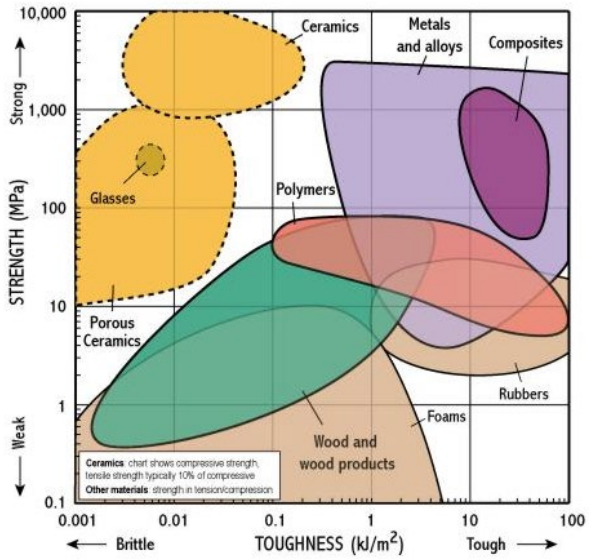

Figure 4 - Fracture Toughness of Materials

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Composite vs Epoxy FJC

- Due to its lower strength, stiffness, and fracture toughness, an epoxy will likely chip, crack, peel, spall, flake, and/or blister before a composite will under similar loading.

Testing

- Fracture Toughness
  - Specimen is pre-cracked, then a tensile machine takes the sample to failure.
  - The ability to resist fracture is calculated based on the results.

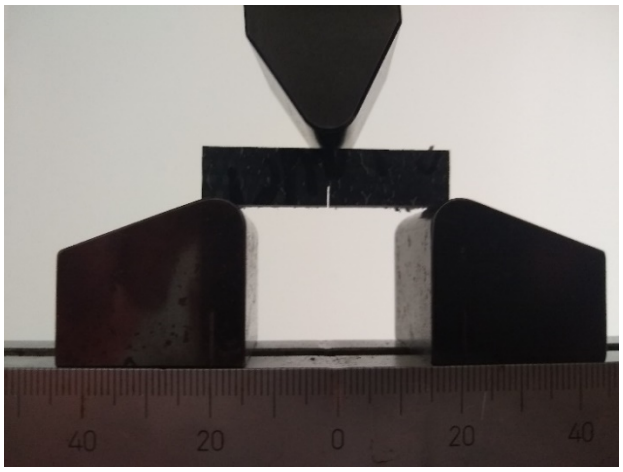

Figure 5 - Specimen used for fracture toughness testing

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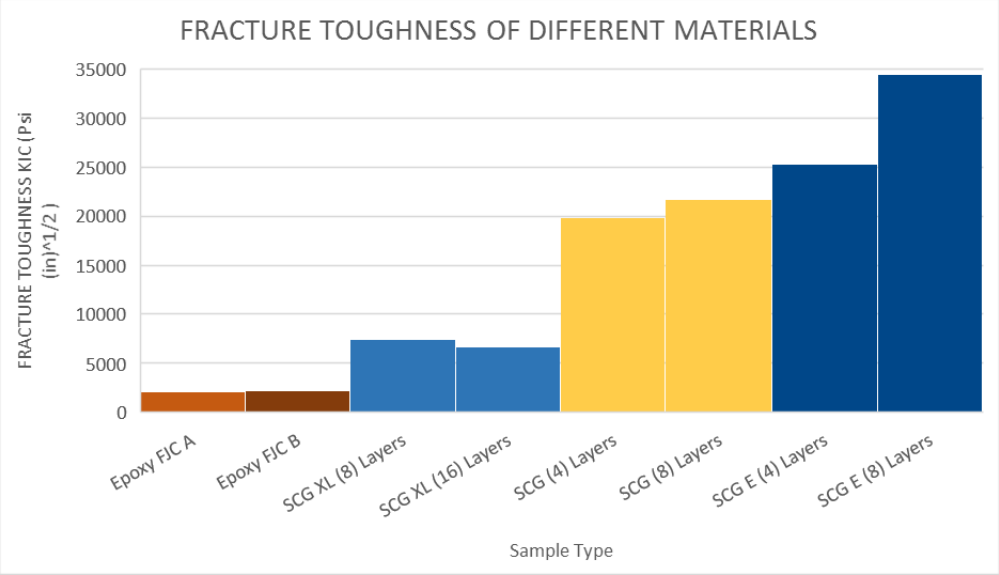

Samples	K_c $(psi \cdot \sqrt{in})$	K_c $(MPa \cdot \sqrt{m})$
Epoxy FJC A	2,112	2.3
Epoxy FJC B	2,245	2.5
SCG XL (8) Layers	7,409	8.1
SCG XL (16) Layers	6,715	7.4
SCG (4) Layers	19,830	21.8
SCG (8) Layers	21,668	23.8
SCG E (4) Layers	25,308	27.8
SCG E (8) Layers	34,378	37.8

CONCLUSION:

- The strength of composite are about 10-30 times greater than neat epoxy FJC's.
- The stiffness of composites are about 10-20 times greater than neat epoxy FJC's.
- The fracture toughness of Scar-Guard is about 10-15 times greater than neat epoxy FJC's.
- Composites offer an undeniable advantage in field performance over neat epoxy FJC's.

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