STATIC AND DYNAMIC BEHAVIOR OF SCARF-REPAIRED THICK-SECTION COMPOSITE PLATES

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Objectives

Characterize the strength and toughness of scarf-repaired composites subjected to static and dynamic axial impact loads

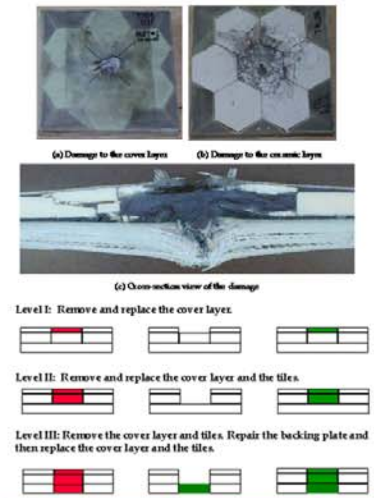
Methodology

Test scarf-repaired composites using the Instron universal test frame and the Split Hopkinson Pressure Bar (SHPB)

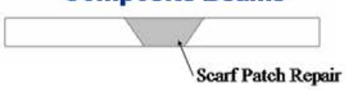
Desired Criteria for Repair of CIA (Cover Layer Side)

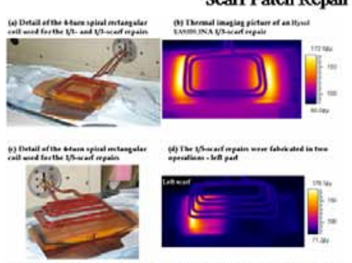
- Renew structural, ballistic, FST and signature performance
- One-step process for multiple interfaces
- Preparation and heating/curing from outer surface (one-side access)
- Vacuum consolidation and gap filling
- Variable damage area
- Rapid portable process for field and depot repairs

Levels of Repair for CIA



Fabrication of Repaired Composite Beams





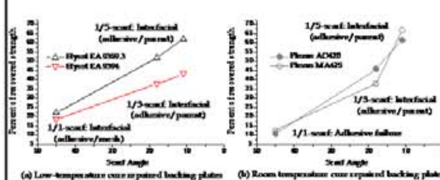
Induction-Heating of the Low-Temperature Cure Adhesives

Bending Stiffness (per unit width) of Repaired Backing Plates

	Bending moment at failure / unit width (N-m/m)			
	Hysol EA9359.3 NA	Hysol EA9394	Plexus MA425	Plexus AO420
1/1-scarf (45°)	1968	1645	1128	952
1/3-scarf (18.4°)	4603	3338	3357	4052
1/5-scarf (11.3°)	5492	3827	5905	5443

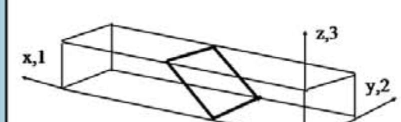
The structural performance of the 1/3- and 1/5-scarf angles improve significantly as the scarf angle is reduced

Renewal in Static Strength of the Repaired Backing Plates



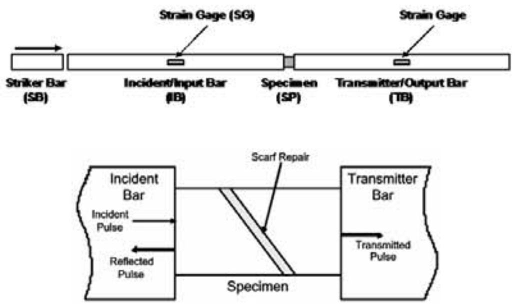
It is observed that the Hysol EA9359.3 repaired beams restored as much as 62% of the control strength of the backing plates, compared with only 43% for the beams repaired with the EA9394 adhesive. The improved performance of the Hysol EA9359.3 may be attributed to the higher elongation and toughness of this adhesive system

Specimen Preparation for Testing in SHPB

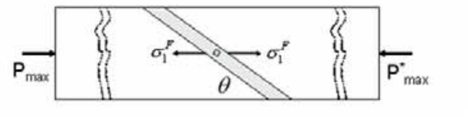


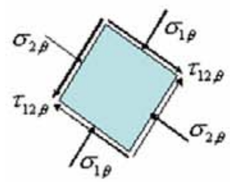
Composite specimens are machined from the scarf repaired backing plates using a slot grinding machine. The nominal cross section of the specimens is 13.5mm x 13.5mm, while the lengths of the specimens are variable as a function of scarf angles

Hopkinson Bar Set-Up for Axial Compression of Scarf-Repaired Composite Specimens



Stress Analysis of Scarf-Repaired Composite Specimens Under Dynamic Axial Compressive Load



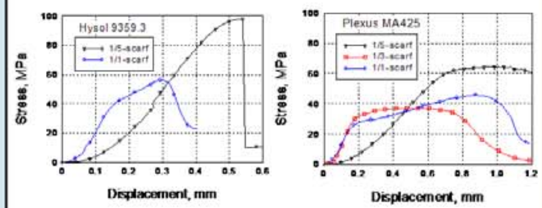


- Calculate stress in the bar σ =(F/A)
- Multiply stress in bar by cross-sectional area of bar to get force, being applied on sample
- Divide force by cross-sectional area of sample to get σ_x

Equation used to calculate stresses in the scarf repair

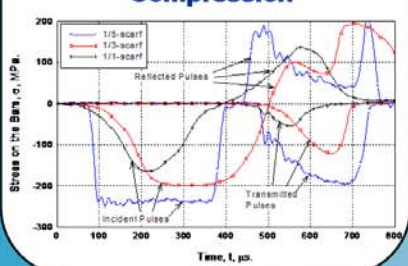
$$\begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix} = \sigma_x \begin{bmatrix} m^2 \\ n^2 \\ -mn \end{bmatrix}$$

Quasi-Static Axial Stress as a Function of Displacement

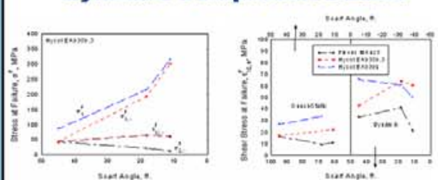


At lower scarf angles (1/1- and 1/3-scarf), the Hysol adhesives showed a yield behavior before the ultimate failure of the specimens. However, at 1/5-scarf, the specimen showed a sudden drop in axial stress indicating failure of the adhesive bond. In all cases, the two parts of the beams are found to adhere together. In the case of Plexus MA425 adhesive, similar axial stress-displacement behavior is observed, however, went under larger axial deformation.

Hopkinson Bar Responses of Hysol EA9359.3 Induction-Cured Scarf-Repaired Composite Specimens Under Axial Compression

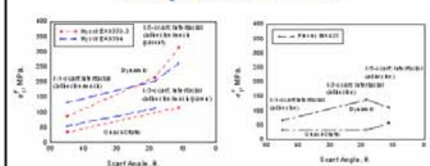


Failure Analysis of Scarf-Repaired Composite Specimens Under Dynamic Compressive Load



The locus of failure is found to be 50% in the adhesive/metal mesh interface and 50% between the adhesive and parent material in the case of Hysol adhesives, except for the 1/1-scarf that is 100% in the adhesive metal mesh interface. In the case of the Plexus adhesive joint, the loci of failure is found to be in the adhesive. The axial compressive stress at failure is transformed to the coordinate system defined by the failure plane (i.e., scarf angle).

Axial Stress at Failure of Scarf-Repaired Composite Specimens Under Dynamic Compressive Load



The results show that the dynamic shear stresses at failure are rate dependent and significantly greater than the static properties. Furthermore, the Hysol adhesives offer higher dynamic shear strength compared to the Plexus adhesive.

Conclusions

- Scarf-repaired beams failed catastrophically in the bondline
- The dynamic axial stress at failure increases as the scarf angle decreases, consistent with the 4-point bend tests
- The dynamic axial stress at failure for all adhesives is higher than the corresponding quasi-static data by a factor of 2-3 for each scarf angle.
- The results show that the dynamic shear stress at failure in the scarf plane is also rate dependent and significantly greater than the static properties
- Higher rate impact testing is needed to fully characterize the strength and energy absorption capabilities of the scarf repair.

Acknowledgments

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