

Physical Properties of Hilti HIT-RE 500 V3 After Irradiation: Slant Shear, Tensile, Flexural, and Compressive

September 2024

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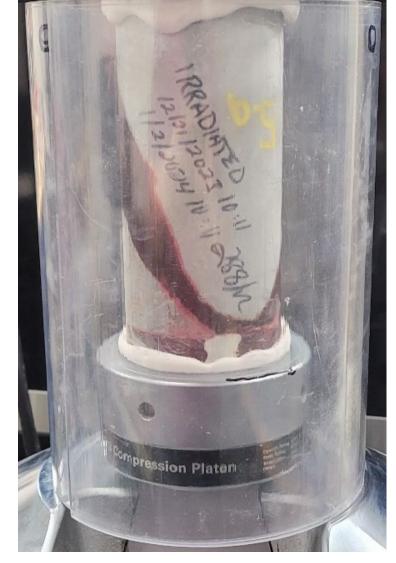
Prepared for the U.S. Department of Energy Under DOE Idaho Operations Office Contract DE-AC07-05ID14517 Kyle Schroeder

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Objective: To determine if Hilti HIT-RE 500 V3 Epoxy Adhesive Anchoring system maintains integrity after obtaining an accumulated dose of 50 kGy various tests must be completed. As per ASTM standard D4000-23 the epoxy family testing in this study should include ASTM D638, D790, D256, and D648. All of these, except D256 and D648 are included in this report as the equipment is not readily available on-site for testing. Additionally, ASTM standards D695 and C882/882M are included since the manufacturer has reported values for these tests and a comparison is merited. This requires the fabrication, irradiation, destruction, and analysis of tensile, flexural, compressive, and slant shear test specimens using ASTM standards D638, D790, D695, and C882/882M respectively. This method requires that a set of irradiated and non-irradiated samples be destructively tested according to the ASTM standards.

Slant Shear





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Post irradiation the epoxy bond strength increases in maximum load and maximum stress; these increases are both 2%. Additionally, due to load frame capacity constraints of 250 kN many of the samples were not taken to failure, this also skews the results obtained in this study. Comparing these results to Hilit's published data is unfair since Hilti's baseline cure time is 14 days, while these samples cured for over 90 days.

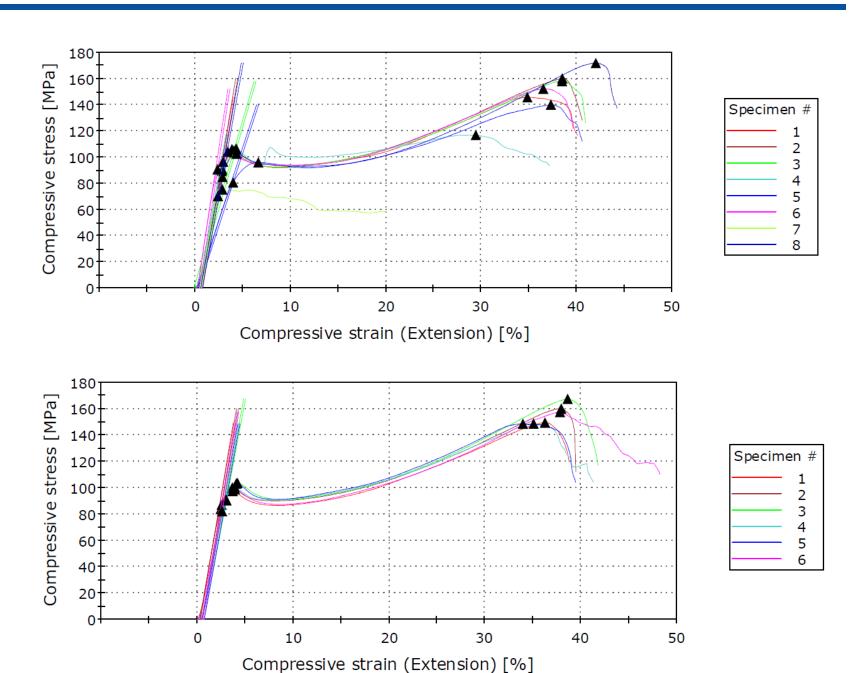
Average max stress

Non-irradiated

22.8 MPa

Irradiated

23.3 MPa



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Figure 2: Slant shear samples, non-irradiated (top), irradiated (bottom).

Specimen Name

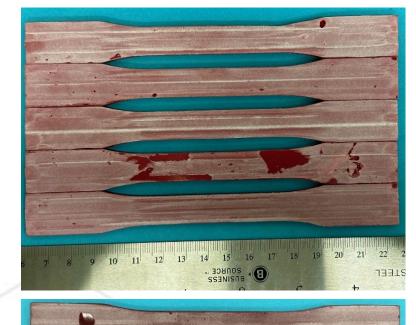
Specimen Name

TI4

TI5

TB3 TB4 TB5

Tensile



The tensile sample set is the only data set that displayed decreases in maximum stress, when compared to Hilti's published values that equates to a decrease in tensile strength of approximately 15%.

Average max stress

Non-irradiated

Irradiated

61.5 MPa Average max strain

61.2 MPa

Non-irradiated

1.36 %

Irradiated 1.34 %

Tensile strain (Strain 1) [%]

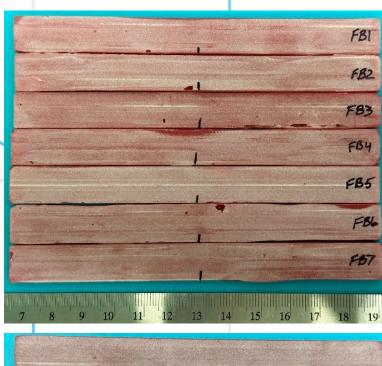
Tensile strain (Strain 1) [%]

Figure 4: Tensile samples, non-irradiated (top), irradiated (bottom).

Figure 3: Tensile samples, non-irradiated (top), irradiated (bottom).

Figure 1: Slant shear samples, non-irradiated (left), irradiated (right).

Flexural



The comparisons in maximum stress and strain made here are less than favorable, during testing many of the non-irradiated samples contained voids in the failure region, a larger sample set is required for higher fidelity.

Average max stress

Non-irradiated 114.7 MPa

Irradiated 120.1 MPa

Average max strain

Non-irradiated Irradiated 2.84 % 3.17 %

Figure 5: Flexural samples, non-irradiated (top), irradiated (bottom).

Table 1: Flexural samples, non-irradiated (top), irradiated (bottom).

Specimen Label	Strain at P _{max} , ε _f (%)	P _{max} (N)	break, σ _{fb} (MPa)	Elasticity (Tangent) (MPa)
FB1	2.34	190.05	108.08	5784.54
FB2	2.97	202.63	116.49	5411.17
FB3	2.83	197.39	111.27	5407.63
FB4	2.94	194.20	115.28	5612.91
FB5	-	-	-	- "
FB6	-	-	-	-
FB7	3.11	201.63	122.16	6066.92
Mean, μ	2.84	197.18	114.65	5656.63
Standard Deviation, s	0.30	5.2	5.4	280
μ -3 s	2.0	180	98	4800
			Flexural	Modulus
	Strain at		Stress at	of
Specimen Label	Strain at P _{max} , ε _f	P _{max} (N)	Stress at Break,	of Elasticity
Specimen Label		P _{max} (N)		Elasticity
Specimen Label	P_{max} , ϵ_f	P _{max} (N)	Break, σ _{fb}	Elasticity (Tangent)
	P _{max} , ε _f (%)		Break, σ _{fb} (MPa)	Elasticity (Tangent) (MPa)
FI1	P _{max} , ε _f (%)	216.83	Break, σ _{fb} (MPa) 121.10	Elasticity (Tangent) (MPa) 5811.24
FI1 FI2	P _{max} , ε _f (%) 3.36 3.19	216.83 225.75	Break, σ _{fb} (MPa) 121.10 121.59	(Tangent) (MPa) 5811.24 5882.77
FI1 FI2 FI3	P _{max} , ε _f (%) 3.36 3.19 3.41	216.83 225.75 228.76	Break, σ _{fb} (MPa) 121.10 121.59 119.00	Elasticity (Tangent) (MPa) 5811.24 5882.77 5694.92
FI1 FI2 FI3 FI4	P _{max} , ε _f (%) 3.36 3.19 3.41 3.29	216.83 225.75 228.76 220.52	Break, σ _{fb} (MPa) 121.10 121.59 119.00 120.74	Elasticity (Tangent) (MPa) 5811.24 5882.77 5694.92 5781.63
FI1 FI2 FI3 FI4 FI5	P _{max} , ε _f (%) 3.36 3.19 3.41 3.29 2.77	216.83 225.75 228.76 220.52 201.70	Break, σ _{fb} (MPa) 121.10 121.59 119.00 120.74 117.97	Elasticity (Tangent) (MPa) 5811.24 5882.77 5694.92 5781.63 5673.58
FI1 FI2 FI3 FI4 FI5 FI6	P _{max} , ε _f (%) 3.36 3.19 3.41 3.29 2.77 3.03	216.83 225.75 228.76 220.52 201.70 211.53	Break, σ _{fb} (MPa) 121.10 121.59 119.00 120.74 117.97 120.33	Elasticity (Tangent) (MPa) 5811.24 5882.77 5694.92 5781.63 5673.58 6050.74

Compression



Figure 6: Irradiated compression samples

Average max stress

Non-irradiated **Irradiated** 114.7 MPa 120.1 MPa

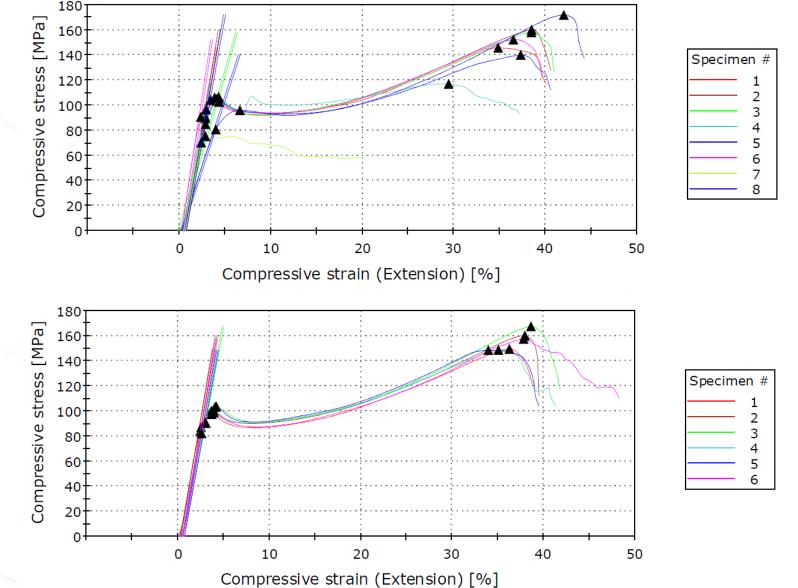


Figure 6: Compression samples, non-irradiated (top), irradiated (bottom).

Results: Data analysis indicates that the material generally strengthens after exposure to 50 kGy, though this comes with increased brittleness as observed in tensile and compression tests. The slant shear tests are particularly insightful, showing adhesive bond strength at the concrete-epoxy interface far exceeding manufacturer claims, with some measurements up to 100% higher. This comparison may be influenced by the longer cure time of over 90 days for test samples versus the manufacturer's 14 days, allowing for enhanced bond maturity. The assessment of both irradiated and non-irradiated samples is reliable, as they were prepared simultaneously using independent verification and adhering to ASTM standards. While the technical merit of the tests is established, extending the analysis to additional samples would provide more robust conclusions. The study's breadth was limited by resource constraints, suggesting that achieving more comprehensive data would require a substantial dedicated research effort. Despite the need to discard some outliers, adherence to ASTM standards and independent verification ensure the data's usefulness. Considering literature review and experimental results, there's no evidence suggesting the material is unsuitable for its intended load bearing uses after irradiation to 50 kGy. The information herein is pertinent for future calculations involving the use of Hilti HIT-RE 500 V3 in scenarios where the expected lifetime radiation dose is 50 kGy or less.

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