

# Benecor, Inc.

Engineered Honeycomb Structures



# Benecor Laser Welded Titanium Honeycomb Core Mechanical Properties Database

This database details the configurations and mechanical properties of Benecor's laser welded titanium honeycomb core. It provides the data needed for selecting laser welded titanium honeycomb core for aerospace and commercial applications. Benecor's titanium honeycomb core offers superior strength-to-weight and stiffness-to-weight ratios compared to other non-metallic and aluminum honeycomb core. Titanium honeycomb core bonded with carbon fiber face sheets offer several advantages over aluminum, foam and nomex sandwich structures.


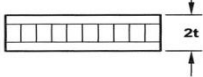
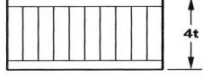
- Galvanic/thermal compatibility
- Higher operating temperature
- Eliminates corrosion issues
- Fluid intrusion/leakage can be eliminated
- Carries load after high impact damage
- Damage readily visible and repairable
- Offers significant weight reduction and life cycle cost savings over nomex and aluminum honeycomb
- Compatible with BMI resins



Graphite/Titanium Core Bonded Panel

# Benecor Laser Welded Titanium Honeycomb Core Mechanical Properties Database

The following chart exhibits how honeycomb stiffens a sandwich structure without significantly increasing the weight of the structure.

	Solid Metal Sheet	Sandwich Construction	Thicker Sandwich
			
Relative Stiffness	100	700 7 times more rigid	3700 37 times more rigid
Relative Strength	100	350 3.5 times as strong	925 9.25 times as strong
Relative Weight	100	103 3.5% increase in weight	106 6% increase in weight

## Titanium Honeycomb Designation

ALLOY - CELL SIZE - FOIL THICKNESS- SQUARE CELL SIZE - DENSITY

Example: Ti3Al2.5V - 1/8 - 0.001 - 4.78

Ti3Al2.5V - is the titanium alloy used

1/8 - is the square cell size in fractions of an inch

0.001-is the nominal reference foil thickness in inches

4.78 - is the nominal density in pounds per cubic foot

## HONEYCOMB SPECIFICATIONS

The following information is needed when honeycomb is specified:

- Cell Size
- Foil Thickness
- Cell Height/Core Thickness
- L' and W' dimensions
- Density
- Application
- Tolerances

# Compressive Mechanical Properties of Benecor's Laser Welded Titanium Honeycomb Core

	Thickness	0.25 inch		0.50 inch		0.625 inch	
Nom. Density (cell size/foil thickness)		Ult. Comp. Strength	Core Comp. Modulus	Ult. Comp. Strength	Core Comp. Modulus	Ult. Comp. Strength	Core Comp. Modulus
[lb/ft <sup>3</sup> ]		[psi]	[ksi]	[psi]	[ksi]	[psi]	[ksi]
4.78 (.125"/.001")	Average	611.03	55.99	580.72	71.14	588.23	81.47
	Std Dev	40.53	5.10	46.04	10.43	49.22	7.68
	COV*	0.07	0.09	0.08	0.15	0.08	0.09
5.61 (.108"/.001")	Average	754.63	73.39	731.99	94.10	721.23	98.11
	Std Dev	53.77	11.25	54.16	10.56	47.75	12.01
	COV	0.07	0.15	0.07	0.11	0.07	0.12
7.17 (.125"/.0015")	Average	1306.61	111.30	1260.03	149.04	1240.74	148.19
	Std Dev	67.74	5.80	54.38	14.83	51.83	22.23
	COV	0.05	0.05	0.04	0.10	0.04	0.15
8.41 (.108"/.0015")	Average	1611.63	169.89	1565.39	218.08	1554.84	224.16
	Std Dev	174.25	22.85	162.44	30.83	96.17	35.28
	COV	0.11	0.13	0.10	0.14	0.06	0.16
9.56 (.125"/.002")	Average	1756.12	145.68	1697.12	213.75	1706.94	230.24
	Std Dev	123.52	12.59	104.39	20.09	116.76	14.89
	COV	0.07	0.09	0.06	0.09	0.07	0.06
11.21 (.108"/.002")	Average	2241.98	183.61	2180.95	277.59	2192.59	312.82
	Std Dev	171.65	15.82	161.34	21.65	164.89	14.96
	COV	0.08	0.09	0.07	0.08	0.08	0.05

\*Note that COV are fractions and not percentages throughout this table.

# Stabilized Compression Test Results of Benecor's Laser Welded Titanium Honeycomb Core

	Thickness	0.25 inch		0.50 inch	
Nom. Density (cell size/foil thickness)		Ult. Comp. Strength	Core Comp. Modulus	Ult. Comp. Strength	Core Comp. Modulus
[lb/ft <sup>3</sup> ]		[psi]	[ksi]	[psi]	[ksi]
4.78 (.125"/.001")	Average Std Dev COV*	NO DATA		601.4 21.24 0.035	70.1 4.54 0.065
5.61 (.108"/.001")	Average Std Dev COV	794.5 55.88 0.07	72.96 12.63 0.173	795.9 26.76 0.030	89.7 11 0.123
7.17 (.125"/.0015")	Average Std Dev COV	1377.5 111.24 0.081	123.84 19.43 0.157	1287.4 56.37 0.044	156.49 17.94 0.115
8.41 (.108"/.0015")	Average Std Dev COV	1773.3 83.37 0.047	149.63 10.44 0.07	1670.9 55.81 0.033	192.83 17.35 0.09
9.56 (.125"/.002")	Average Std Dev COV	1934.5 69.96 0.036	156.84 11.6 0.074	1794.2 71.74 0.040	222.9 30.14 0.135
11.21 (.108"/.002")	Average Std Dev COV	2447.5 77.92 0.032	158.03 12.07 0.076	2339.9 54.79 0.023	276 50.85 0.184

\*Note that COV are fractions and not percentages throughout this table.

# Plate Shear Strength and Core Modulus of Benecor's Laser Welded Titanium Honeycomb Core Pg. 1 of 2

Density [lb/ft <sup>3</sup> ] (cell size /foil thickness)	Core Thickness [in.]		SHEAR STRENGTH [psi] / CORE MODULUS [ksi]					
			RIBBON		TRANSVERSE		ANGLE	
4.78 (.125"/.001")	0.25	AVERAGE	637.58	35.46	541.95	24.73	512.23	28.45
		STD DEV	97.20	6.37	23.50	3.78	18.10	4.72
		COV	0.15	0.18	0.04	27.61	0.04	0.17
	0.50	AVERAGE	514.36	32.44	418.34	21.94	427.97	25.55
		STD DEV	20.82	6.11	16.77	1.81	10.90	4.47
		COV	0.04	0.19	0.04	0.08	0.03	0.17
	0.625	AVERAGE	505.33	32.55	411.98	22.48	434.44	28.06
		STD DEV	22.99	2.80	14.38	2.91	15.48	3.15
		COV	0.05	0.09	0.03	0.13	0.04	0.11
5.61 (.108"/.001")	0.25	AVERAGE	666.13	35.68	615.86	30.16	570.93	33.18
		STD DEV	29.66	3.44	27.30	4.81	26.54	4.81
		COV	0.04	0.10	0.04	0.16	0.05	0.14
	0.50	AVERAGE	599.68	47.53	504.59	29.99	518.48	32.70
		STD DEV	48.48	36877.84	32.00	4.92	20.68	3.71
		COV	0.08	0.78	0.06	0.16	0.04	0.11
	0.625	AVERAGE	509.57	33.10	599.88	44.53	497.96	31.85
		STD DEV	25.18	3.42	35.66	6.73	29.44	8.31
		COV	0.05	0.10	0.06	0.15	0.06	0.26
7.17 (.125"/.0015")	0.25	AVERAGE	1001.45	42.03	920.87	39.29	787.96	40.64
		STD DEV	58.52	3.52	39.02	4.22	30.21	4.43
		COV	0.06	0.08	0.04	0.11	0.04	0.11
	0.50	AVERAGE	837.13	55.83	789.64	47.40	692.91	46.94
		STD DEV	31.96	9.28	46.58	9.80	22.47	4.08
		COV	0.04	0.17	0.06	0.21	0.03	0.09
	0.625	AVERAGE	805.27	61.36	741.27	49.02	667.65	53.92
		STD DEV	53.52	15.25	23.21	3.40	19.56	7,82
		COV	0.07	0.25	0.03	0.07	0.03	0.15

\*Note that COV are fractions and not percentages throughout this table.

# Plate Shear Strength and Core Modulus of Benecor's Laser Welded Titanium Honeycomb Core Pg. 2 of 2

Density [lb/ft <sup>3</sup> ] (cell size/ foil thickness)	Core Thickness [in.]		SHEAR STRENGTH [psi] / CORE MODULUS [ksi]					
			RIBBON		TRANSVERSE		ANGLE	
8.41 (.108"/.0015")	0.25	AVERAGE	1161.78	51.77	1064.22	45.85	912.12	48.95
		STD DEV	68.35	6.32	40.78	4.30	37.01	4.80
		COV	0.06	0.12	0.04	0.09	0.04	0.10
	0.50	AVERAGE	984.81	72.14	928.46	68.89	800.88	65.54
		STD DEV	44.14	9.23	70.71	13.02	19.16	8.38
		COV	0.04	0.13	0.08	0.19	0.02	0.13
	0.625	AVERAGE	915.72	78.58	867.49	67.47	772.53	79.87
		STD DEV	112.94	8.88	43.51	4.92	21.32	13.08
		COV	0.12	0.11	0.05	0.07	0.03	0.16
9.56 (.125"/.002")	0.25	AVERAGE	1077.58	51.22	1093.30	53.51	889.75	52.85
		STD DEV	28.78	7.36	43.43	10.37	28.29	6.91
		COV	0.03	0.14	0.04	0.19	0.03	0.13
	0.50	AVERAGE	947.60	75.76	915.84	77.70	787.40	79.94
		STD DEV	45.93	7.56	44.00	9.50	30.36	14.85
		COV	0.05	0.10	0.05	0.12	0.04	0.19
	0.625	AVERAGE	875.42	130.05	936.57	210.89	726.86	95.85
		STD DEV	73.72	52.85	33.09	84.80	17.01	7.78
		COV	0.08	0.41	0.04	0.40	0.02	0.08
11.21 (.108"/.002")	0.25	AVERAGE	1431.01	53.59	1211.95	46.39	1027.82	50.64
		STD DEV	68.48	5.14	105.49	3.74	58.46	12.63
		COV	0.05	0.10	0.09	0.08	0.06	0.25
	0.50	AVERAGE	1197.82	147.93	1057.43	117.72	938.23	92.80
		STD DEV	130.85	80.49	61.41	55.59	45.94	33.73
		COV	0.11	0.54	0.06	0.47	0.05	0.36
	0.625	AVERAGE			1145.88	119.30	938.35	172.17
		STD DEV	NO DATA		28.07	24.74	20.60	83.53
		COV			0.02	0.21	0.02	0.49

\*Note that COV are fractions and not percentages throughout this table.

# Tensile Test Results for Panels: Benecor's Laser Welded Titanium Honeycomb Core Bonded to BMI Graphite Face Sheets

Nom. Density (cell size/foil thickness)	Avg. Dens.	Core Thickness	Ult Tensile Strength	Standard Deviation	COV*
[lb/ft <sup>3</sup> ]	[lb/ft <sup>3</sup> ]	[in.]	[psi]		
4.78 (.125"/.001")	5.07	0.25	1294.6	129.61	0.100
		0.50	1281.7	164.93	0.129
5.61 (.108"/.001")	5.38	0.25	1350.1	289.70	0.215
		0.50	1623.6	200.40	0.123
7.17 (.125"/.0015")	7.17	0.25	1208.8	360.75	0.298
		0.50	1511.6	245.01	0.162
		1.00	1385.2	200.80	0.145
8.41 (.108"/.0015")	8.35	0.25	1652.0	274.20	0.166
		0.50	1650.6	249.20	0.151
		1.00	1742.8	338.00	0.194
9.56 (.125"/.002")	9.52	0.50	1736.8	167.80	0.097
		1.00	1460.9	130.90	0.090
11.21 (.108"/.002")	10.89	0.50	1872.7	226.80	0.121
		1.00	1638.5	237.50	0.145

\*Note that COV are fractions and not percentages throughout this table.

# Beam Flexure Results for Panels: Benecor's Laser Welded Titanium Honeycomb Core Bonded to BMI Graphite Face Sheets Pg. 1 of 2

Beam		Flexure	GRADE 9 TI, BMI FACE SHEET, CYTEC ADHESIVE			
			RIBBON		TRANSVERSE	
Density [lb/ft <sup>3</sup> ] (cell size/foil thickness)	core thickness [in]		Ult. Strength [psi]	2% Yld Strength [psi]	Ult. Strength [psi]	2% Yld Strength [psi]
4.78 (.125"/.001")	0.25	average	580.2	573.8	490.5	488
		std dev	31.82	29.74	12.66	17.32
		COV*	0.055	0.052	0.026	0.036
	0.50	average	486.1	497.4	394.4	393.1
		std dev	25.96	17.94	23.91	13.97
		COV	0.053	0.036	0.061	0.036
5.61 (.108"/.001")	0.25	average	635.7	599.5	572.3	564.4
		std dev	33.47	118.94	23.91	24.13
		COV	0.058	0.198	0.042	0.043
	0.50	average	509.9	492.7	519.8	**
		std dev	43.41	38.32	5.86	
		COV	0.085	0.078	0.011	
7.17 (.125"/.0015")	0.25	average	998.7	948	944.9	852.5
		std dev	122.4	108.6	53.3	53.1
		COV	0.123	0.115	0.056	0.062
	0.50	average	763.9	717.2	740.8	**
		std dev	31.6	55.4	10.0	
		COV	0.041	0.077	0.013	
	1.00	average	747.5	**	661.0	**
		std dev	39.0		16.8	
		COV	0.052		0.025	

\*Note that COV are fractions and not percentages throughout this table.

\*\* Specimen failed before reaching yielding.

# Beam Flexure Results for Panels: Benecor's Laser Welded Titanium Honeycomb Core Bonded to BMI Graphite Face Sheets Pg. 2 of 2

Beam Flexure		GRADE 9 TI, BMI FACE SHEET, CYTEC ADHESIVE					
Nom. Density [lb/ft <sup>3</sup> ] (cell size/foil thickness)	core thickness [in]		RIBBON		TRANSVERSE		
			Ult. Strength [psi]	2% Yld Strength [psi]	Ult. Strength [psi]	2% Yld Strength [psi]	
8.41 (.108"/.0015")	0.25	average	1142.9	1113.9	1120.1	1035.9	
		std dev	74.8	68.05	44.14	29.02	
		COV*	0.065	0.061	0.039	0.028	
	0.50	average	953.07	**	869.6	**	
		std dev	46.67		19.8		
		COV*	0.049		0.023		
	1.00	average	869.6	**	796.5	**	
		std dev	35.88		29.58		
		COV*	0.041		0.025		
	9.56 (.125"/.002")	0.50	average	930.4	**	880.6	696.3
			std dev	31.31		19.58	
			COV*	0.041		0.025	
1.00		average	942.0	**	857.7	**	
		std dev	24.5		16.75		
		COV*	0.0		0.019		
11.21 (.108"/.002")	0.50	average	1094.4	**	933.3	725.3	
		std dev					
		COV*					
	1.00	average	1241	**	975.7	**	
		std dev					
		COV*					

\*Note that COV are fractions and not percentages throughout this table.

\*\* Specimen failed before reaching yielding.