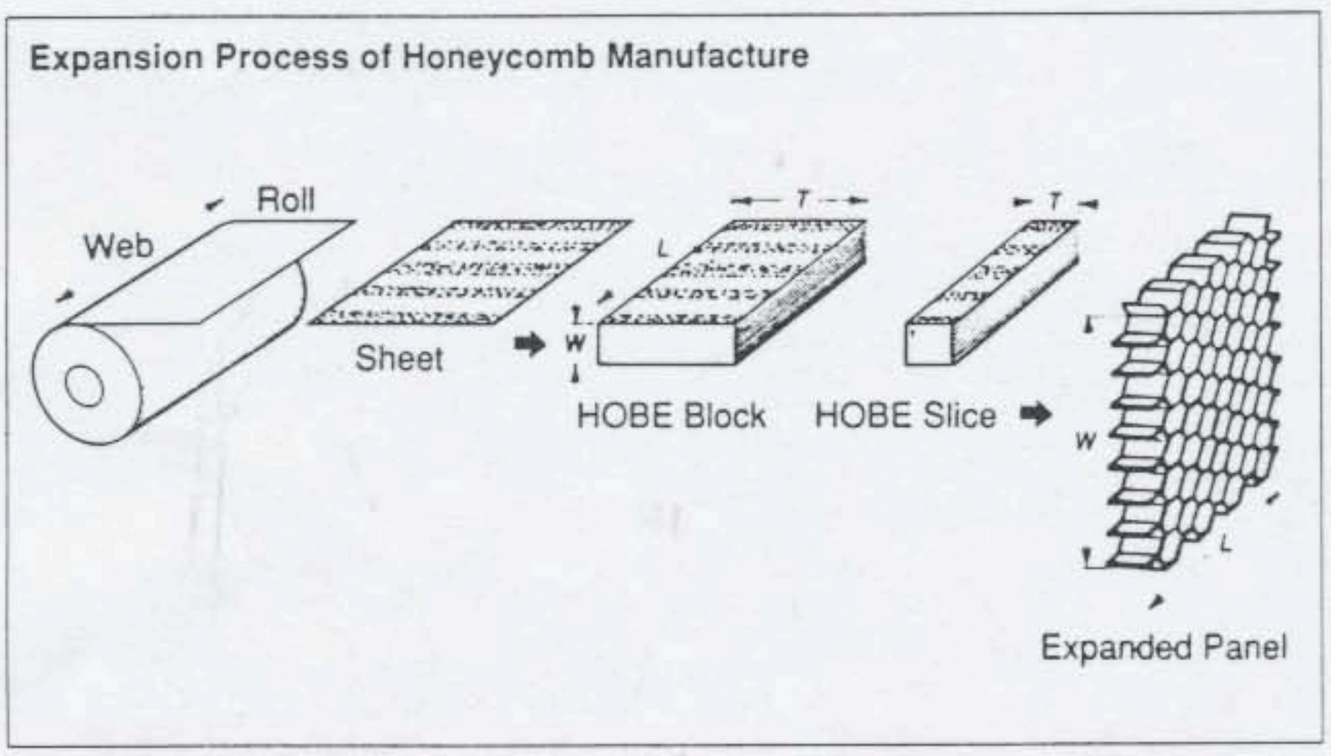
How Honeycomb Is Manufactured

Honeycomb is made primarily by the "expansion" method. The corrugated process is most common for the high density honeycomb materials.

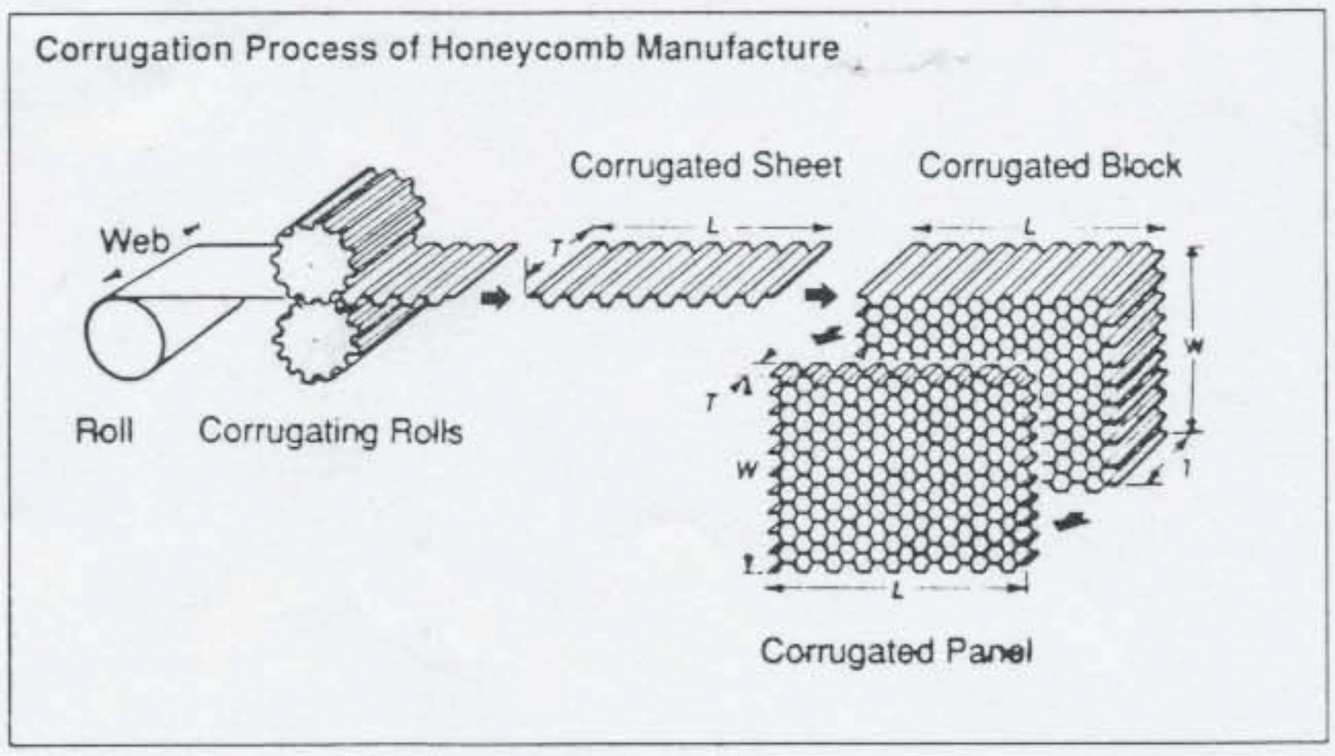


Expansion Process

The honeycomb fabrication process by the "expansion" method begins with the stacking of sheets of the web material on which adhesive node lines have been printed. The adhesive lines are then cured to form a HOBE® (Honeycomb Before Expansion) block.

The HOBE block itself may be expanded after curing to give an expanded block. Slices of the expanded block to the desired "T" dimension may then be taken. Alternately, HOBE slices can be cut from the HOBE block to appropriate "T" dimension and expanded.

Each HOBE slice is then expanded to the desired cell shape giving an expanded panel. The expanded panels are trimmed to the desired "L" dimension (ribbon direction) and "W" dimension (transverse to the ribbon). The "L", "W" and "T" dimensions are expressed in inches.



Corrugated Process

The corrugated process of honeycomb manufacture is normally used to produce products in the higher density range. In this process adhesive is applied to the corrugated nodes, the corrugated sheets are stacked into blocks, the node adhesive cured, and panels are cut from these blocks to the required core thickness. The dimensional terminology for blocks made by the corrugated process is identical to that for expanded honeycomb.

Sandwich Construction

The facings of a sandwich panel used as a beam act similarly to the flanges of an I beam by taking the bending loads — one facing in compression and the other in tension. Expanding this comparison further, the honeycomb core corresponds to the web of the I beam. This core resists the shear loads, increases the stiffness of the structure by spreading the facings apart, but unlike the I beam's web, gives continuous support to the flanges or facings. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity.

Figure 1

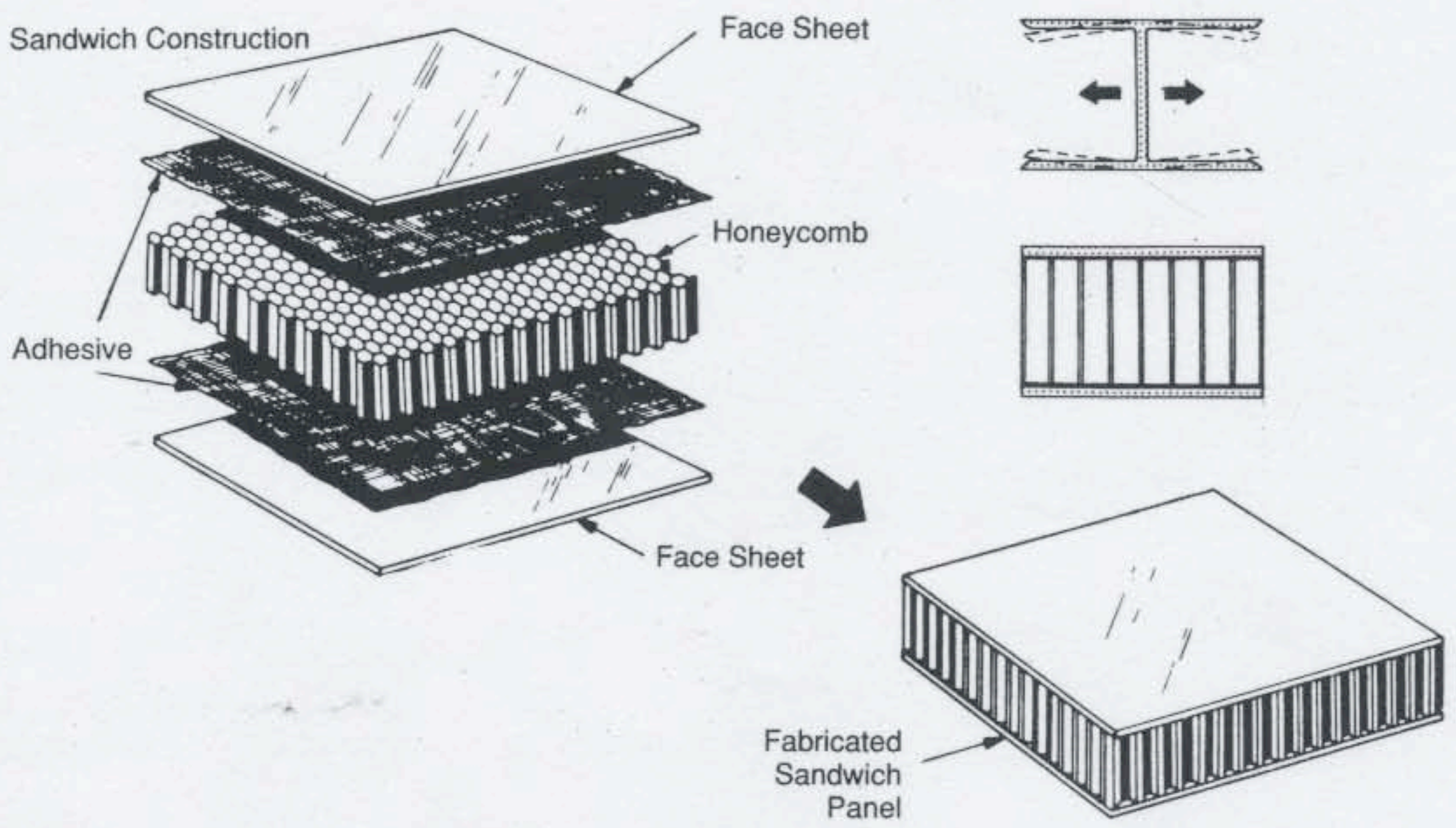
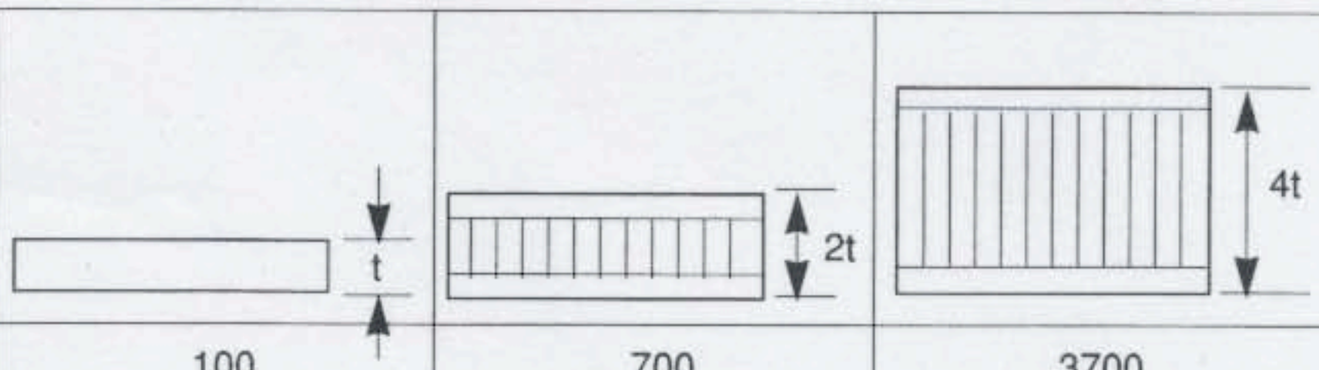


Figure 2



Relative Stiffness (D)	100	700	3700
Relative Strength	100	350	925
Relative Weight	100	103	106

A striking example of how honeycomb stiffens a structure without materially increasing its weight.

Mechanical Properties and Test Methods

The test methods used for the honeycomb properties listed in this bulletin are based on MIL-STD-401 and the applicable ASTM Standards. The properties and the test methods employed are outlined below. Unless specifically stated, the test properties listed have been performed at room temperature.

Density and Thickness Measurements

The density of honeycomb is expressed in pounds per cubic foot. Hexcel certifies that aerospace grade core will not vary in density by more than ± 10% from listed nominal values. The density tolerance for commercial grade aluminum core is ± 15%. The density of production honeycomb is normally measured on full size expanded panels.

Physical dimensions and weight measurements are taken to within 0.5%. The thickness is measured to the nearest .001 inch in accordance with ASTM C 366, Method B.

Compressive Properties

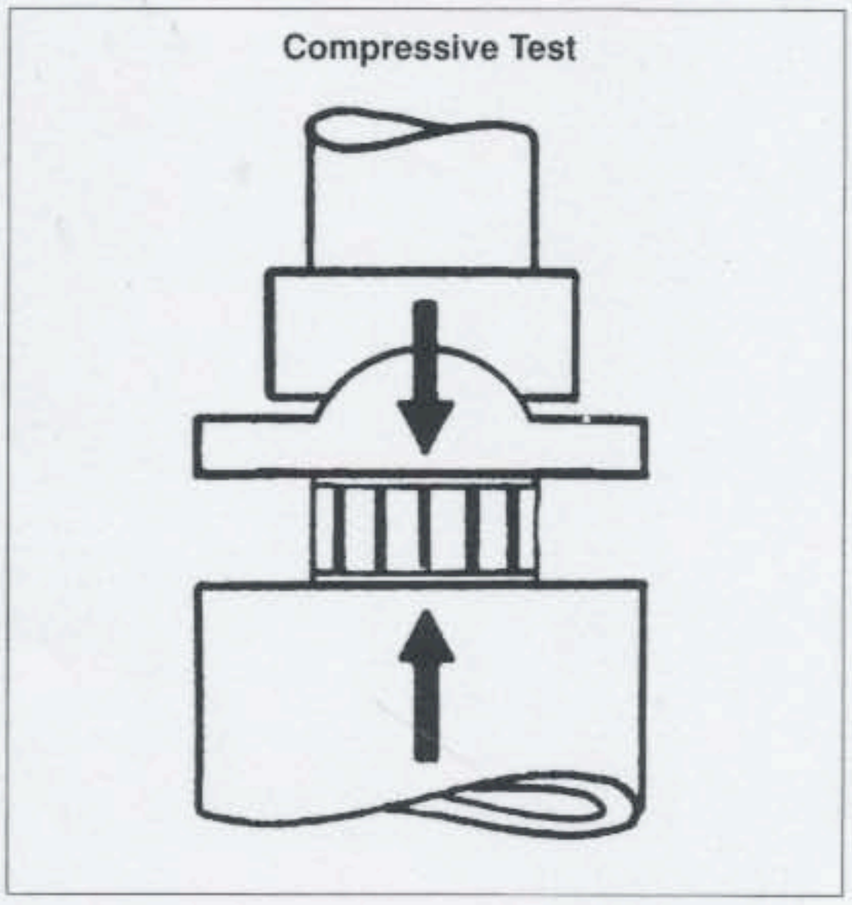
The stabilized compressive strength (also called flatwise compressive strength) represents the ultimate compressive strength of the honeycomb in pounds per square inch when loaded in the "T" direction. Normally for this test, facings are adhesively bonded to the honeycomb material.

The stabilized compressive modulus, also expressed in pounds per square inch, is determined from the slope of the initial straight line portion of the stress-strain curve.

The bare compressive strength is the ultimate compressive strength of the core in pounds per square inch when loaded in the "T" direction without stabilization of the cell edges. The value is normally used for an acceptance criteria since this test is easier and faster to perform.

Test Methods

The standard specimen size for bare and stabilized compressive tests is 3" "L" x 3" "W" x 0.625" "T" for aluminum honeycomb and 3" "L" x 3" "W" x 0.500" "T" for non-metallic cores. For cell sizes 1/2 inch or larger, a 4 x 4 inch or even 6 x 6 inch specimen size is used to reduce the error developed by edge effect on small samples. Stabilized compressive specimens are normally prepared by bonding 2024 T3 0.020" thick facings to each side.

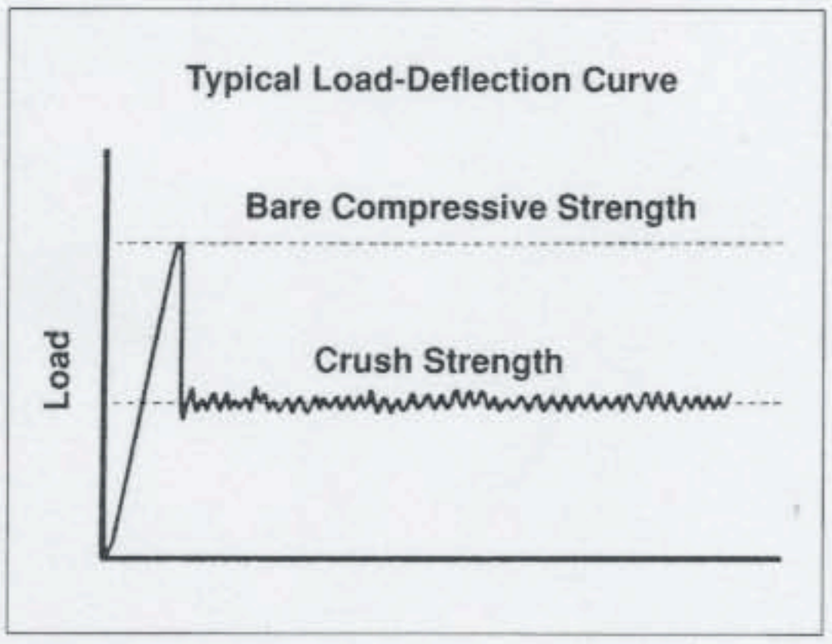


Both bare and stabilized compressive tests are conducted with self-aligning loading heads. Unless otherwise specified, the loading rate used is .020 inches per minute. Deflection recordings are made with a displacement transducer which measures the relative movement of the loading and bearing surfaces through the center of the specimen.

Crush Strength

After honeycomb has exceeded its ultimate compressive strength, it will continue to deform plastically and uniformly "crush." The load deflection curve shows such a typical response.

The average crush load per unit cross-sectional area is defined as the crush strength, expressed in pounds per square inch. Honeycomb will crush at virtually a constant stress level (dependent on the core material and density), hence its absorption capacity is predictable, making it ideal for energy



absorption applications. When used in this manner, the core is often pre-crushed slightly to remove the compressive peak in the load deflection curve.

Test Methods

Fixed loading and bearing plates are used for crush strength tests and a deflectometer is employed to measure the travel of the crosshead of the test machine. In order to obtain a meaningful crush load-deflection curve, a minimum core thickness of 0.625 inches should be used.

It should be noted that the crush strength values presented in this bulletin are typical static test results. It has been found that under dynamic loading, these values increase non-linearly with impact velocity, and numbers as much as 30% higher have been reported.

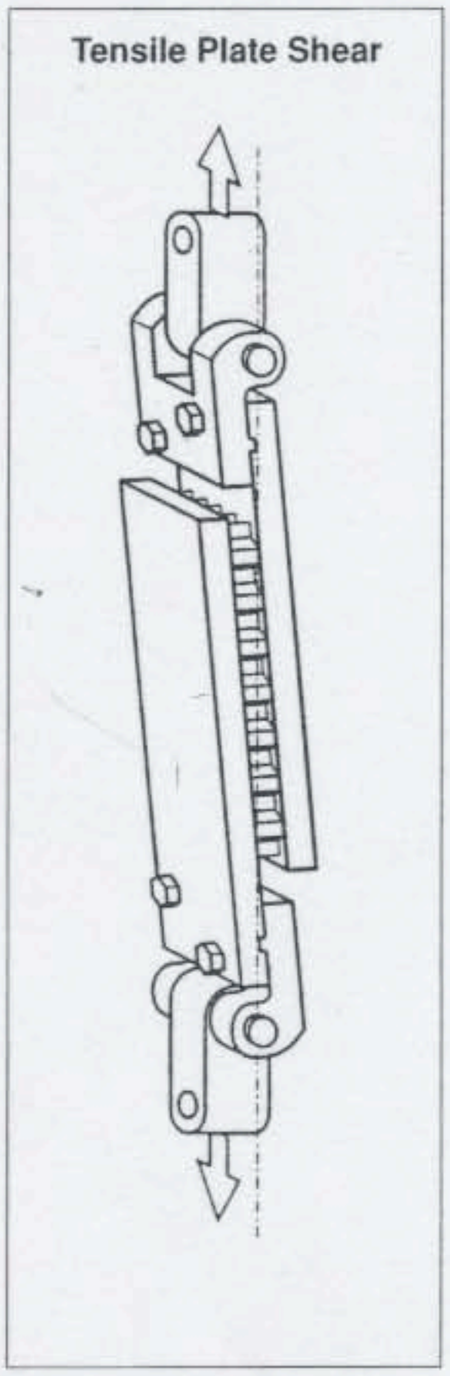
"L" and "W" Shear Properties

The shear strength of honeycomb as presented in this bulletin refers to the ultimate stress in pounds per square inch when a shear load is applied parallel to the "L"-"W" plane. The shear modulus is the slope of the initial straight line portion of the stress-strain curve. The values so obtained are dependent upon the orientation of the applied loading with respect to the "L" and "W" dimensions, being highest in the "L" direction and lowest in the "W" direction for hexagonal honeycomb.

Test Methods

Plate Shear Test Method

The shear strength and modulus values presented in this bulletin were obtained using the compressive and/or tensile plate shear method. The specimen size for aluminum honeycomb is normally 7.5" x 2" x 0.625" "T". Non-metallic honeycombs test sample size is 6" x 2" x 0.500" "T." Thicknesses conform to MIL-C-7438 and MIL-C-8073 respectively. The specimens are bonded to 1/2 inch thick steel loading plates and then tested as shown.



The loading rate is normally 0.020 inches per minute. Shear deflections are measured with a displacement transducer that senses the relative movement of the two plates. Since some non-metallic materials will not always have a truly linear stress-strain curve (particularly at elevated temperatures), the shear modulus is normally calculated from the slope of the initial straight line portion of the load-deflection curve.

Honeycomb with densities of 8.0 pcf and higher are sometimes difficult to fail in shear by the plate shear method because of the high shear loads introduced to the adhesive bond between the core and steel plates. In some cases, shear data from beam-flexure testing will be more applicable. This is true for thicker and also heavier density cores.

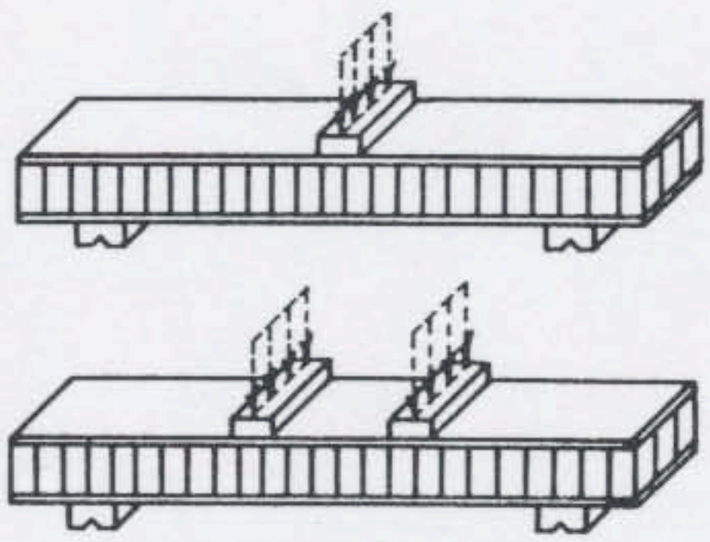
Beam-Flexure Test Method

Although the plate shear method is preferred for obtaining actual honeycomb shear strength and modulus results, the beam-flexure test is often used to evaluate overall sandwich performance. Experience indicates that since these values are very much dependent on the facing thickness, facing material and loading conditions, the calculated honeycomb properties may vary considerably from one test series to the next. Many types of beam-flexure tests have been used. The two most common techniques are shown schematically below.

The specimen size is 8 x 3 inches. The span between supports is 6" and either one or two point loading can be used. The distance between the load pads for two point loading is normally 1/3 the span. For additional details refer to MIL-C-7438.

Again, it should be stressed that the resulting beam-flexure data should only be considered a test of the facings, adhesives and core acting as a composite sandwich structure. Core shear values obtained by flexure tests are often higher than those obtained from plate shear tests (See page 11 for correlation factors between plate shear and flexure data).

Beam-Flexure



Flatwise Tensile

Flatwise tensile is used to measure bond strength of adhesives and/or the tensile strength of the honeycomb core. Most structural adhesives will be stronger than aluminum cores up to about 6 pcf. This test is most useful in determining skin preparation, bonding conditions, and prepreg adhesions. See MIL STD- 401 and ASTM C297.

Additional Mechanical Properties

Numerous tests on both core materials and bonded sandwich have been run by Hexcel laboratory personnel for qualification to military specifications, or for internal R & D purposes. Contact your local Hexcel application engineer for particular information.

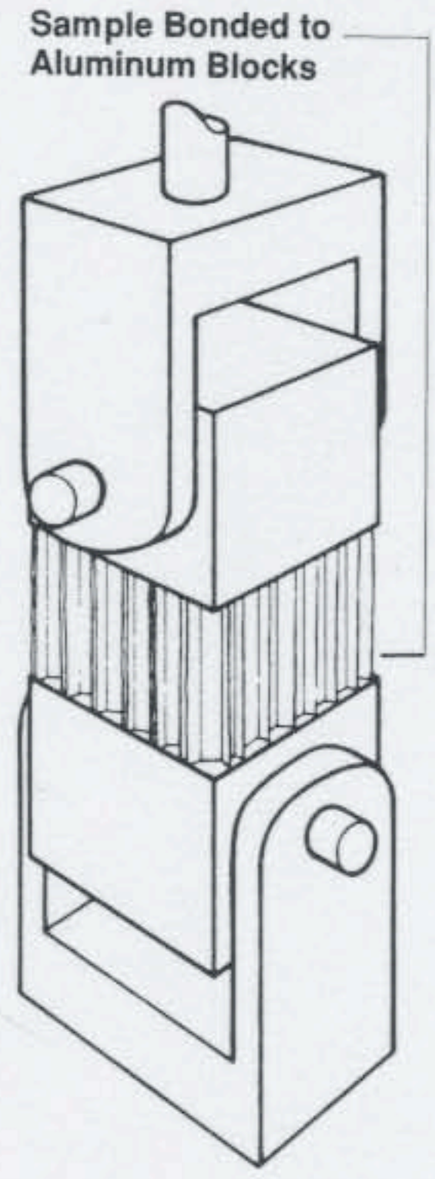
Classification of Mechanical Properties

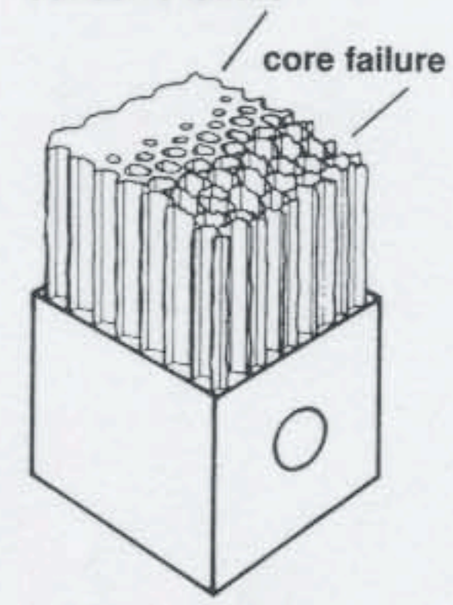
Hexcel classifies its mechanical properties data into three categories dependent upon the extent of the testing being reported. These classifications are as follows:

1. "Preliminary" — Data resulting from a very limited amount of testing are indicative of the properties expected, but do not necessarily represent the mean values of a normal scatter of test data. Generally, "preliminary" values are obtained from testing one or two blocks or lots of a honeycomb type. Numbers followed by the superscript "P" indicate preliminary data.

2. "Typical" — Data represents extensive testing of many blocks or lots of a particular honeycomb material. A typical value is the mean average of a relatively large number of test values.

3. "Minimum" — Hexcel guarantees the minimum individual properties listed on standard honeycomb types. Where no minimum property is given, a value may be provided by your local Hexcel representative.





Note: Hexcel reserves the right to periodically review and update the property values shown in this bulletin as additional test data becomes available. It is suggested that Hexcel be contacted for the latest available information when test methods other than those described here are employed.