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MATERIAL - HRP - 3/8 OX AND 3/4 OX HEXCEL FOAM
FILLED CORE - SHEAR STRENGTH AND SHEAR MODULUS - DETERMINATION OF...
TEST DATA MEMORANDUM

F T D M N O. 3048
MODEL 55
TEST NO. 50-2224

TEST:
MATERIAL - HRP - 3/8 OX AND 3/4 OX HEXCEL FOAM FILLED CORE -
SHEAR STRENGTH AND SHEAR MODULUS - DETERMINATION OF

OBJECT: To obtain core shear strength and shear modulus of rigidity data
on Hexcel's HRP 3/8 OX 3.1 lbs./ft. \(^2\) and 3/4 OX 2.2 lbs./ft. \(^2\) core
material as foam filled sandwich specimens.

TEST SPECIMENS AND PROCEDURES:
Test specimens and procedures are listed in Table I.

RESULTS:
Results are shown in Table II.

DISCUSSION:
Shear strength and shear modulus data of typical sections of the Centaur
Thermal Shroud are needed to evaluate the structural integrity and fabrica-
tion processes of the latest design. The purpose of this test was to
obtain this information from shop fabricated specimens by testing the
specimens in accordance with OD/FW's FZM-2352 (page B-003-1) Specification.
The span lengths were specified in the test request as 7" and 14". All
specimens were produced by the OD/FW production shop under similar condi-
tions to production Centaur parts.

Test results for foam-filled core specimens indicate higher shear moduli and
core shear results with this light density core material as compared to non-
foam filled core specimens. Results of the 1.75" core thickness specimens
were according to predictions, but considerable variations were observed in
the 0.7" thick core specimens. Apparently the specimen configuration, skin
thickness, core thickness and/or span lengths were incompatible with the
two span length shear modulus formula (FZM 2352). For example, the calculated
shear modulus values for the 3/8 OX "W" ribbon direction are negative
values. If several foam filled beams of this thickness (0.7") had been
tested as single length beams and the span varied to such an extent to yield
a bending factor (FZM 2352, B-003-2, \(B\) of \(l\)) between \(0.5\) and \(1\), the shear modulus
would have most probably been reliably accurate and this experimentally de-
termined short span, when doubled would probably fill the requirements for the
two span length shear modulus formula. The data listed in Table II was con-
firmed by a retest of one beam for each of the .7" thick core and appears in
Table II.

CONCLUSIONS:
The core shear strength and shear modulus was determined on Hexcel's HRP 3/8
OX 3.1 lbs./ft. \(^2\) and 3/4 OX 2.2 lbs./ft. \(^2\) core material as foam filled beams
and the data is listed in Table II.

The tests described in this report were performed in the Engineering Materials
Laboratory between 9-3-62 to 9-18-62.

WITNESS:

DATE: September 21, 1962

See Supplemental Sheets S-1 thru S-5.
TABLE I

TEST SPECIMENS AND TEST PROCEDURES OF FOAM FILLED HECCEL'S HRP 3/8 OX 3.1 lbs./ft.\(^3\) AND 3/4 OX 2.2 lbs./ft.\(^3\) CORE MATERIAL

A. TEST SPECIMENS: Twenty-four specimens were furnished as follows:

<table>
<thead>
<tr>
<th>NO.</th>
<th>RIBBON</th>
<th>APPROX. SIZE</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L</td>
<td>3&quot; x 16&quot;</td>
<td>.7&quot;</td>
</tr>
<tr>
<td>2</td>
<td>W</td>
<td>&quot;</td>
<td>.7</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
<td>&quot;</td>
<td>1.75</td>
</tr>
<tr>
<td>4</td>
<td>W</td>
<td>&quot;</td>
<td>1.75</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>&quot;</td>
<td>.7</td>
</tr>
<tr>
<td>6</td>
<td>W</td>
<td>&quot;</td>
<td>.7</td>
</tr>
</tbody>
</table>

B. FABRICATION OF SPECIMENS: The panels were of three types as listed below:

1. Skins, 3 ply 181 FMS-0031 Class III bonded with Narmoo 306 adhesive to core (.7" thick) 3/8 OX filled with American Latex 2 lbs./ft.\(^3\) 602 foam.

2. Skins, 3 ply 181 FMS-0031 Class III bonded with 306 adhesive to core (1.75" thick) 3/8 OX filled with 602 foam.

3. Skins, 3 ply 181 FMS-0031 Class III bonded with 306 adhesive to core (.7" thick) 3/4 OX filled with 602 foam.

C. TESTING OF SPECIMENS: All specimens as described above were tested with loads and load pads as follows:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>LOAD RATE</th>
<th>LOAD RATE</th>
<th>LOAD PADS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IN./MIN.</td>
<td>IN./MIN.</td>
<td>SUPPORT LOAD SUPPORT LOAD</td>
</tr>
<tr>
<td>1</td>
<td>273</td>
<td>.09</td>
<td>.5&quot; .75&quot; 1.5&quot; 3&quot;</td>
</tr>
<tr>
<td>2</td>
<td>666</td>
<td>.10</td>
<td>.75 1.5 1.25 2.5</td>
</tr>
<tr>
<td>3</td>
<td>229</td>
<td>.09</td>
<td>.75 1.5 1.00 2.00</td>
</tr>
</tbody>
</table>

The specimens were tested first using the 1½" span and then the 7" span in a Baldwin Universal test machine at room temperature and the slopes recorded. These data were then used to compute the core shear and shear modulus using the formulas per F2M 2352.
### TABLE II

**Core Shear and Shear Modulus Results for Hexcel's HRP 3/8 ox and 3/4 ox foam filled core material.**

<table>
<thead>
<tr>
<th>SPEC. NO.</th>
<th>RIBBON DIRECTION</th>
<th>CORE THICK (IN.)</th>
<th>LOAD TO FAILURE (LBS)</th>
<th>P/A short span (LBS/IN.)</th>
<th>P/A long span (LBS/IN.)</th>
<th>SHEAR MOD. (PSI)</th>
<th>CORE SHEAR SHEAR (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>L</td>
<td>1.75</td>
<td>1310</td>
<td>16,231</td>
<td>1.386</td>
<td>7,106</td>
<td>128</td>
</tr>
<tr>
<td>2.</td>
<td>L</td>
<td>1.75</td>
<td>1265</td>
<td>15,723</td>
<td>1.329</td>
<td>7,011</td>
<td>120</td>
</tr>
<tr>
<td>3.</td>
<td>L</td>
<td>1.75</td>
<td>1355</td>
<td>16,319</td>
<td>1.367</td>
<td>7,191</td>
<td>129</td>
</tr>
<tr>
<td>4.</td>
<td>L</td>
<td>1.75</td>
<td>1275</td>
<td>16,555</td>
<td>1.375</td>
<td>7,202</td>
<td>120</td>
</tr>
<tr>
<td><strong>AVERAGE</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,278</td>
<td>124</td>
</tr>
<tr>
<td>5.</td>
<td>W</td>
<td>1.75</td>
<td>1955</td>
<td>31,482</td>
<td>7,002</td>
<td>22,185</td>
<td>188</td>
</tr>
<tr>
<td>6.</td>
<td>W</td>
<td>1.75</td>
<td>2030</td>
<td>32,051</td>
<td>7,225</td>
<td>17,785</td>
<td>195</td>
</tr>
<tr>
<td>7.</td>
<td>W</td>
<td>1.75</td>
<td>2110</td>
<td>35,714</td>
<td>7,364</td>
<td>22,317</td>
<td>202</td>
</tr>
<tr>
<td>8.</td>
<td>W</td>
<td>1.75</td>
<td>1865</td>
<td>34,722</td>
<td>7,185</td>
<td>20,272</td>
<td>178</td>
</tr>
<tr>
<td><strong>AVERAGE</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,610</td>
<td>191</td>
</tr>
<tr>
<td>9.</td>
<td>L</td>
<td>.7</td>
<td>782</td>
<td>8,000</td>
<td>1,181</td>
<td>29,585</td>
<td>179</td>
</tr>
<tr>
<td>10.</td>
<td>L</td>
<td>.7</td>
<td>787</td>
<td>8,039</td>
<td>1,168</td>
<td>32,599</td>
<td>180</td>
</tr>
<tr>
<td>11.</td>
<td>L</td>
<td>.7</td>
<td>793</td>
<td>8,064</td>
<td>1,163</td>
<td>31,113</td>
<td>181</td>
</tr>
<tr>
<td>12.</td>
<td>L</td>
<td>.7</td>
<td>815</td>
<td>8,196</td>
<td>1,173</td>
<td>36,788</td>
<td>186</td>
</tr>
<tr>
<td><strong>AVERAGE</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32,521</td>
<td>182</td>
</tr>
<tr>
<td>13.</td>
<td>W</td>
<td>.7</td>
<td>982</td>
<td>12,821</td>
<td>1,531</td>
<td>-158,818*</td>
<td>226</td>
</tr>
<tr>
<td>14.</td>
<td>W</td>
<td>.7</td>
<td>998</td>
<td>13,514</td>
<td>1,563</td>
<td>-93,047*</td>
<td>225</td>
</tr>
<tr>
<td>15.</td>
<td>W</td>
<td>.7</td>
<td>965</td>
<td>13,158</td>
<td>1,534</td>
<td>-101,534*</td>
<td>218</td>
</tr>
<tr>
<td>16.</td>
<td>W</td>
<td>.7</td>
<td>979</td>
<td>12,870</td>
<td>1,546</td>
<td>-181,913*</td>
<td>223</td>
</tr>
<tr>
<td><strong>AVERAGE</strong>:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-133,828</td>
<td>223</td>
</tr>
</tbody>
</table>
# TABLE II (Cont'd)

Core shear and shear modulus results for HFXCEL's HRP 3/8 ox and 3/4 ox foam filled core material.

<table>
<thead>
<tr>
<th>SPEC. NO.</th>
<th>RIBBON DIRECTION</th>
<th>CORE THICK. (IN.)</th>
<th>TYPE</th>
<th>LOAD TO FAILURE (LBS)</th>
<th>P/A SHORT SPAN (LBS/IN.)</th>
<th>P/A LONG SPAN (LBS/IN.)</th>
<th>SHEAR MOD. (PSI)</th>
<th>CORE SHEAR (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.</td>
<td>L</td>
<td>.7</td>
<td>3</td>
<td>513</td>
<td>4,790</td>
<td>1,000</td>
<td>6,747</td>
<td>117</td>
</tr>
<tr>
<td>18.</td>
<td>L</td>
<td>.7</td>
<td>3</td>
<td>527</td>
<td>4,914</td>
<td>1,003</td>
<td>7,281</td>
<td>120</td>
</tr>
<tr>
<td>19.</td>
<td>L</td>
<td>.7</td>
<td>3</td>
<td>520</td>
<td>4,831</td>
<td>1,018</td>
<td>6,671</td>
<td>117</td>
</tr>
<tr>
<td>20.</td>
<td>L</td>
<td>.7</td>
<td>3</td>
<td>498</td>
<td>4,854</td>
<td>984</td>
<td>7,096</td>
<td>112</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,948</td>
<td>117</td>
</tr>
<tr>
<td>21.</td>
<td>W</td>
<td>.7</td>
<td>3</td>
<td>815</td>
<td>9,524</td>
<td>1,471</td>
<td>28,146</td>
<td>185</td>
</tr>
<tr>
<td>22.</td>
<td>W</td>
<td>.7</td>
<td>3</td>
<td>895</td>
<td>9,823</td>
<td>1,511</td>
<td>29,179</td>
<td>202</td>
</tr>
<tr>
<td>23.</td>
<td>W</td>
<td>.7</td>
<td>3</td>
<td>830</td>
<td>10,000</td>
<td>1,492</td>
<td>34,507</td>
<td>187</td>
</tr>
<tr>
<td>24.</td>
<td>W</td>
<td>.7</td>
<td>3</td>
<td>811</td>
<td>9,398</td>
<td>1,486</td>
<td>25,027</td>
<td>189</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29,265</td>
<td>191</td>
</tr>
</tbody>
</table>

## RETEST VALUES

<table>
<thead>
<tr>
<th>SPEC. NO.</th>
<th>RIBBON DIRECTION</th>
<th>CORE THICK. (IN.)</th>
<th>TYPE</th>
<th>LOAD TO FAILURE (LBS)</th>
<th>P/A SHORT SPAN (LBS/IN.)</th>
<th>P/A LONG SPAN (LBS/IN.)</th>
<th>SHEAR MOD. (PSI)</th>
<th>CORE SHEAR (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.</td>
<td>L</td>
<td>.7</td>
<td>1</td>
<td>827</td>
<td>8,237</td>
<td>1,284</td>
<td>27,088</td>
<td>189</td>
</tr>
<tr>
<td>26.</td>
<td>W</td>
<td>.7</td>
<td>1</td>
<td>1100</td>
<td>12,919</td>
<td>1,563</td>
<td>-214,586*</td>
<td>226</td>
</tr>
<tr>
<td>27.</td>
<td>L</td>
<td>.7</td>
<td>3</td>
<td>539</td>
<td>4,651</td>
<td>1,037</td>
<td>5,968</td>
<td>122</td>
</tr>
<tr>
<td>28.</td>
<td>W</td>
<td>.7</td>
<td>3</td>
<td>864</td>
<td>9,728</td>
<td>1,555</td>
<td>25,287</td>
<td>197</td>
</tr>
</tbody>
</table>

**NOTE:** Shear moduli values for the 0.7" thick core specimens are questionable because specimen configuration and test span lengths are not compatible with the 2-span length formula specified in FZM-2352. *Note negative values for Type I specimens. In this test it appears that core shear data is consistent and reproducible and would be considerably more reliable in determining the foam filled core strength than the shear modulus.
SANDWICH TWO SPAN LENGTH
SHEAR BEAM TEST

SCOPE: This method is designed for use in determining the core shear modulus and shear strength of flat sandwich beams by use of a flexural two span length test. This method is recommended as being the most accurate for the determination of core shear modulus.

TEST SPECIMEN:

A. The general test specimen configuration shall be as given on the introductory page to this method.

B. The core thickness, "t_c", recommended for this test is usually 0.450 to 0.750 inches. A core thickness tolerance of ± 0.005 inches is recommended. If possible, a tolerance of ± 0.003 inches should be used.

C. The specimen width, "B", should be not less than twice the specimen thickness, "t". (B 2t) B = 3 inches is usually selected.

D. The short span length, "L_2", for test should be not less than twice the specimen length, "B". (L_2 2B) L_2 = 6 inches is usually selected.

E. The long span length, "L_1", for test should be exactly twice the short span length, "L_2". (L_1 = 2L_2) L_1 = 12 inches when L_2 = 6 inches.

F. The specimen length, "S", should be two inches longer than the long span, "L_1", to allow one inch overhangs beyond the support points of the test jig. When L_2 = 6 inches and L_1 = 12 inches, S = 14 in.

G. The sandwich face thicknesses, "t_f", should be the standard thickness which is closest to the value calculated below:

\[
  t_f = \frac{L_2^2 t_c (1 - \frac{2}{Ef})}{6 t_c Ef}, \text{ inches}
\]

G. must either be taken from previous data or it must be estimated, for the particular temperature of test. Clad aluminum alloy faces are usually selected for this test for temperatures below 300°F. Some values of Ef and Ef are as follows:

<table>
<thead>
<tr>
<th>Aluminum Alloy Faces</th>
<th>Ef @ R.T.</th>
<th>Ef @ 260°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clad 7075-T6</td>
<td>0.33</td>
<td>9.2 x 10^6 psi</td>
</tr>
<tr>
<td>Clad 2024-T86</td>
<td>0.34</td>
<td>9.5 x 10^6 psi</td>
</tr>
</tbody>
</table>
Test Specimen (Cont'd.)

G. (Cont'd.)

If reinforced plastic faces are used the values of "h" and "E_f" must be estimated from reported data. Because of variations of "h" and "E_f" within a particular laminate, reinforced plastics are not recommended for sandwich faces in a shear modulus test.

H. The face stress in the sandwich specimen during test should never exceed 80% of yield strength. This should be calculated for both the long and short span, as follows:

\[
\begin{align*}
  f_f &= \frac{P_{l1}}{2Bt_f(t + t_c)} 0.80 (F_y), \text{ psi} \\
  f_f &= \frac{Fs_{su}L_2}{2t_f} 0.80 (F_y), \text{ psi}
\end{align*}
\]

\(P_{l1}\) is the maximum load for the long span, as calculated in the test procedure. \(F_{su}\) must either be taken from previous data or it must be estimated, for the particular temperature of test. The value of \(F_y\) for the faces must also be estimated or obtained from data. If either of the two alloys mentioned in (G) on the previous page are used as the faces, a value of \(F_y = 60,000 \text{ psi}\) will be satisfactory for test temperatures below 300°F. If the calculations above show that 80% \(F_y\) will be exceeded, thicker faces must be used on the sandwich specimen.

I. Measure the exact core thickness, "t_c", and face thicknesses, "t_f". Then bond the sandwich panel together using a suitable adhesive between each face and the core. A suitable adhesive is any adhesive that will prevent an initial bond failure during test. A specific adhesive may be specified in the applicable test document.

J. Cut the desired number of test specimens from the resulting sandwich panel and measure the exact width, "B", and thickness "t", of each specimen.

TEST PROCEDURE: (Equal thickness sandwich faces of the same material)

A. Two flexural test jigs are required for this test, one with a span of "L_1" and the other with a span of "L_2", as calculated in (D) and (E) on the previous page. The test is to be performed in a single point load set-up as shown on the introductory pages to this method.
B. To prevent core crushing under the load and reaction points, it will be necessary to provide bearing plates. The bearing plate area in contact with the specimen must be large enough to prevent the compressive stress, at any time during the test, from exceeding 80% of $F_{cu}$. The necessary bearing plate area should be calculated as follows:

\[
\begin{align*}
\text{Long Span (L)}_{1} & \quad \text{(each reaction point)} \\
A &= \frac{P_{1}}{(2)(0.80)(F_{cu})}, \text{ (inches)}^2 \\
(\text{load point}) \\
A &= \frac{P_{1}}{(0.80)(F_{cu})}, \text{ (inches)}^2 \\
\text{Short Span (L)}_{2} & \quad \text{(each reaction point)} \\
A &= \frac{F_{su}B(t + t_{c})}{(2)(0.80)(F_{cu})}, \text{ (inches)}^2 \\
(\text{load point}) \\
A &= \frac{F_{su}B(t + t_{c})}{(0.80)(F_{cu})}, \text{ (inches)}^2
\end{align*}
\]

$P_{1}$ is the maximum load for the long span. $F_{su}$ and $F_{cu}$ must either be taken from previous data or they must be estimated, for the particular temperature of test. The bearing plate width, necessary to give the required area, "A", should be rounded off, upwards, to the nearest 0.25 inch increment so that standard size bearing plates can be used.

C. Position the specimen on the long span (L$_1$) test jig so that there is a one inch overhang beyond each support point. Bring the loading heat of the machine down to contact the specimen at the center of the span and adjust the extensometer probe, supported on the test jig base, so that it contacts the underside of the specimen directly below the load point.
TEST PROCEDURE: (Cont'd.)

D. Load the specimen to the maximum load "P_1" at a constant deflection rate, "H_1", as monitored by a strain pacer. During the test a load vs. deflection graph is to be recorded autographically using a deflection magnification such that the curve will have an approximate 45° slope. Release the load immediately after "P_1" has been reached. Calculate "P_1" and "H_1" as follows:

\[ P_1 = B(0.60) (F_{su})(t + t_c), \text{ pounds} \tag{8} \]

\[ H_1 = \frac{ZL_1^2(1.25)}{bt}, \text{ inches per minute} \tag{9} \]

\[ Z = 0.0015 \text{ inches per inch per minute for aluminum faces} \]
\[ Z = 0.0005 \text{ inches per inch per minute for steel faces} \]
\[ Z = 0.0045 \text{ inches per inch per minute for reinforced plastic faces.} \]

F must be either taken from previous data or must be estimated for the particular temperature of test.

E. Repeat step (C) except that the span length and the deflection rate is to be changed. Also, this time the specimen is to be loaded completely to failure. The specimen is to be positioned on the short span (L_2) test jig so that there are equal overhangs beyond each support point. The specimen is to be loaded to failure at a constant deflection rate of "H_2", as calculated below. Record the failing load and record the load vs. deflection curve as in step (D).

\[ H_2 = \frac{ZL_2^2(2.00)}{bt}, \text{ inches per minute} \tag{10} \]

The "Z" values are the same as for step (D).
TEST PROCEDURE: (Cont'd.)

F. Examine the specimen for acceptable type of failure according to the introductory pages of this method. Calculate core ultimate shear strength and core shear modulus of rigidity as follows:

\[ F_{su} = \frac{P_u}{B(t + t_c)} \text{ psi} \]  
(11)

\[ G_c = \frac{3L_1 t_c (P/\ell_p)}{4Bd^2(8 - R)} \text{ psi} \]  
(12)

\[ R = \frac{(P/\ell_p)^2}{(P/\ell_p)} \]  
(13)

SYMBOLS:

- \( F_{su} \) = Ultimate core shear strength, (psi)
- \( G_c \) = Core shear modulus of rigidity, (psi)
- \( P \) = Applied load at any time during test (lbs)
- \( P_m \) = Maximum load for long span (lbs)
- \( P_f \) = Applied failing load for short span (lbs)
- \( L_1 \) = Long span length (in)
- \( L_2 \) = Short span length (in)
- \( (P/\ell_p)_1 \) = Initial straight line slope of the long span load vs. deflection curve (lbs/in)
- \( (P/\ell_p)_2 \) = Initial straight line slope of the short span load vs. deflection curve (lbs/in)
- \( S \) = Specimen length (in)
- \( B \) = Specimen width (in)
- \( t \) = Specimen thickness (in)
- \( t_c \) = Core thickness (in)
- \( t_{cf} \) = Sandwich face thickness (in)
- \( A_p \) = Bearing plate area in contact with the specimen (in)^2
- \( H \) = Constant deflection rate (in/min)
- \( Z \) = Sandwich face strain rate (in/in/min)
- \( d \) = Distance between the centroids of the sandwich specimen faces (in)
- \( (t + t_c)/2 \) = Poisson's ratio of the sandwich face material
- \( E_f \) = Modulus of elasticity of the sandwich face material (psi)
- \( f_{fr} \) = Stress in the sandwich faces (psi)
- \( f_y \) = Yield strength of the sandwich face material (psi)
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