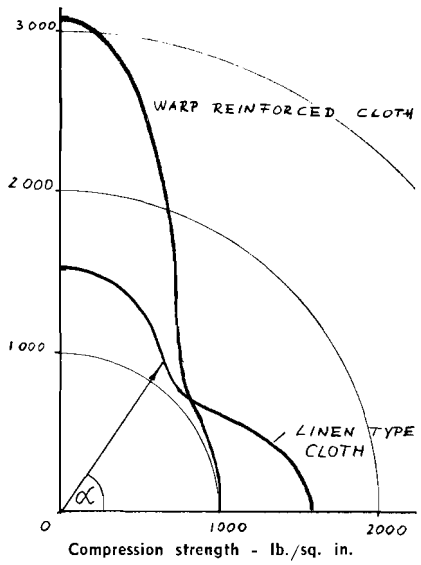

Figure 2. Compression strength of resin impregnated fiberglass as a function of force direction. Manual method.

tion of the force line for linen type cloth and cloth reinforced in warp direction. These values should be compared with those of plywood. The advantage of glass fiber is, therefore, not due to its high strength but only due to its work-ability and high surface smoothness.

1.3 Balsawood As Filler Material:

Simple calculations show that only thin layers of plastic are required to build a glass fiber - balsawood sandwich. For sandwich constructions it is important to have good joints and good possibilities of force transmission between top layers and filler material. Foam and honeycomb materials show big disadvantages which show up in losses of strength and stiffness.

Balsawood has been selected as a result of intense investigations. Its main disadvantage is a wide spread in stress values. Its advantage is its homogeneous structure and as load carrying material the ability to take stresses itself. Its workability is not as good as that of fiberglass, but it can easily be cut, glued and sanded, the main processes used to build gliders.

1.4 Strength of Balsawood:

Balsa itself is not a new aircraft material. Huetter mentioned several years ago the possibility of building a glider with Balsa as prime material (Ref. 2). The main disadvantage of balsawood is the wide spread of stress values, even after introduction of the specific weight as parameter. Fortunately, the lower limit of values is still sufficient when stresses are applied in direction of the grain

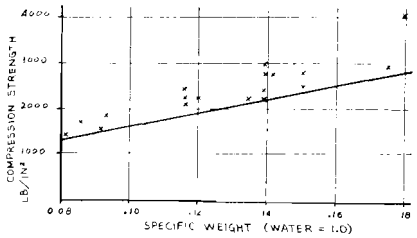

Figure 3. Compression strength of balsawood as a function of specific weight.

(Figure 3). Under 90° to the grain the strength also drops considerably, but this is characteristic for all sorts of wood. The surface of a pure balsa construction, however, would be too soft, it has to be reinforced with an additional layer.

1.5 Properties of The Sandwich Construction:

The combination of fiberglass and balsa obviously offers a good solution for gliders, based on the properties of the two components. The results proved satisfactory, not only due to the good workability, but also because both have about the same strength properties. Figure 4 shows test results of compression strength as a function of the thickness of the fiberglass layer. These values, too, spread because balsa of different strengths have been used. As mentioned before, the advantage of this sandwich method is not due to higher strength, but due to the possibility to build a shell which offers superior stress distribution for bending and tension compared to the "spar" method. Of course, one of the characteristic properties of the fiberglass balsa sandwich is its different strength in different directions.

But especially for aircraft there are main force directions which can be matched by the orientation of the fibers. Use of materials with uniform strength would mean an over-design. For instance, bending is the main force at the wing. Torsion gives only small components with a shell construction. But even this can be considered by using different cloth angles for the different cloth layers.

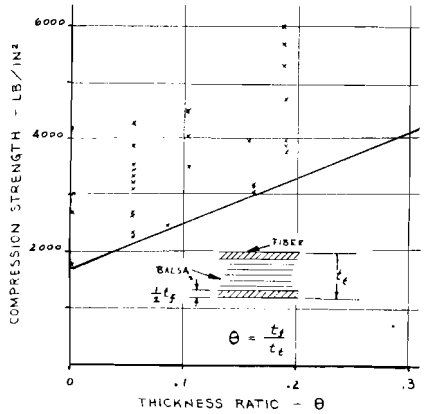

Figure 4. Compression strength of sandwich parts as function of thickness ratio.

This gives a better solution for the shear stresses.

2. DANGER OF BUCKLING:

For a sandwich construction it is important to get all the layers as close to the surface as possible, that means, the filler material should be as thin as possible. The filler thickness, however, is determined by the tendency of buckling. Extensive theoretical investigations have been conducted for sandwich constructions. They all assume that the filler material does not take any normal forces. This is not correct in our case. Bending tests have been made with different samples of sandwich parts in order to determine an average modulus of elasticity resulting from the stiffness of the plate. Of course, there is a different modulus of elasticity in different directions. This required the application of the theory for orthogonal-unisotrope materials (Ref. 3). The results for the "Phoenix" wing were that three vertical webs are required to prevent buckling of the wing. The spacing of the webs had to be small compared to the spacing of the ribs, see Figure 5.

Usually the thickness of the outer layers of a sandwich construction are determined by the loads, the thickness of the filler material is determined by buckling considerations. In the case of fiberglass-balsa combination this division is not as evident. By increas-

Figure 5. Cross section of wing with webs and reinforced center piece.