DESIGN and CONSTRUCTION PARAMETERS for LARGE BIAXIAL TESTING MACHINE

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Comprehensive fabric test data for the design of architectural tension membrane structures is generally lacking within the design community. The design of a large scale tester, able to produce stretch tensile and tear tests both uniaxially and biaxially is the subject of research by the author.

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1. INTRODUCTION

The membrane structures industry is now established worldwide with a supporting design community requiring reliable data for use in designing these structures. Manufacturers data and standard test methods borrowed from other industries are proving to be less than comprehensive and sometimes inappropriate.

A testing machine which can meet the needs of modern membrane structure design is sorely required, and the parameters for design and construction of such is the detailed subject of this factor.

2. SCOPE OF MACHINE TASKS

Biaxial loading of architectural fabrics is the stress condition found in most structures. The desirable tasks for a machine to perform are:

- Biaxial Stretch Testing.
- Uniaxial Stretch Testing.
- Biaxial Tensile Testing.
- Uniaxial Tensile Testing.
- Biaxial Tear Testing.
- Uniaxial Tear Testing.
- Creep Testing.

3. SPECIMEN SIZE & PREPARATION

The key to accuracy of results is the specimen size. The larger the size the smaller the measuring error in percentage terms.

Photo 1 shows a biaxial stretch testing apparatus built by Vesl and used in the laboratory. The frame can deliver a load of up to 4 KN/m for prestress stretch testing.

The sample size is 1200 x 1200mm with a working section of 600 x 600mm.

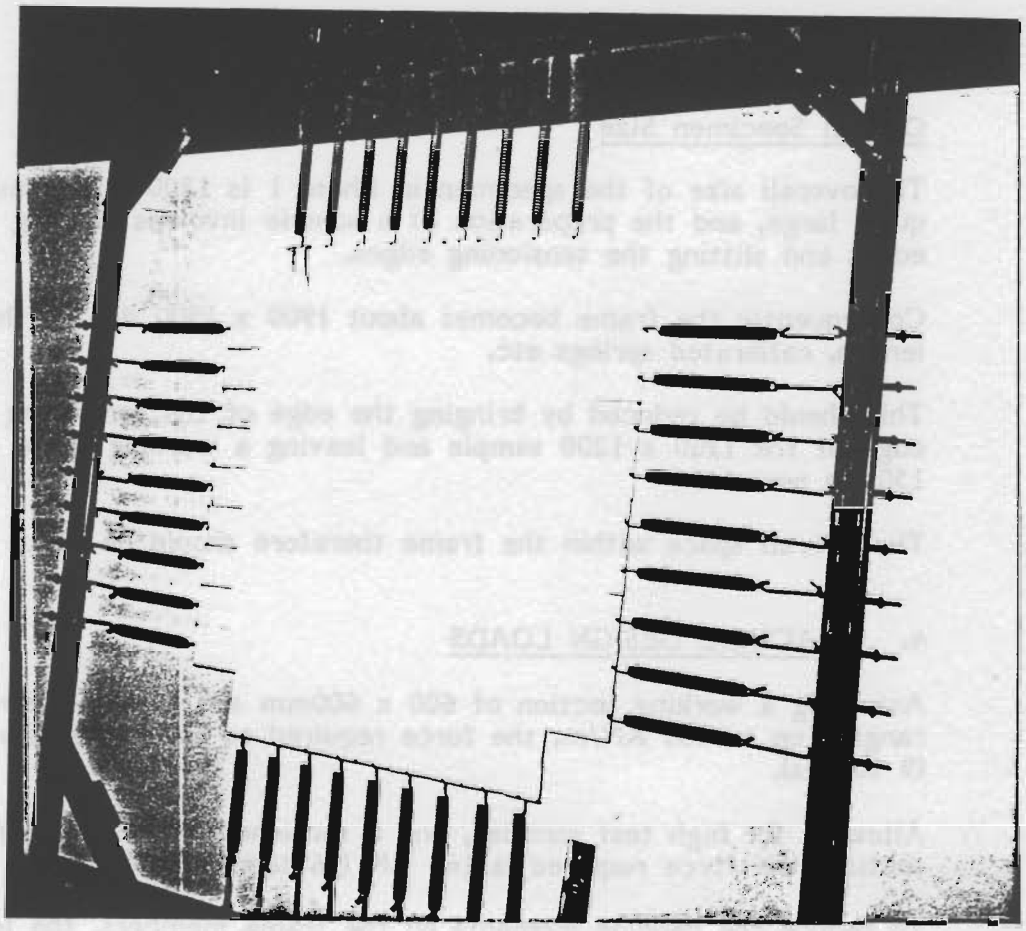

Photo 1: Biaxial Stretch Testing Apparatus.

Most testers the author has reviewed have a working section of the order of 300 x 300mm, and load in the range to 20 KN/m.

The effect on accuracy of measurement is as follows:

If the Warp stretch of a typical Class III sample is 0.3% for prestress load, on a 300mm working length, this corresponds to a stretch of 0.9mm. Assuming a measuring error of 0.25 to 0.5mm, the error is 25% to 50% of the measurement.

If the working section is increased to 600mm, the error is reduced to 12%-25% which is far more acceptable, particularly at the lower range.

Weft stretch is usually 2 to 3 times larger so the error is correspondingly reduced.

Overall Specimen Size

The overall size of the specimen in Photo 1 is 1200 x 1200mm. This is quite large, and the preparation of a sample involves welding a pocket in the edges and slitting the tensioning edges.

Consequently the frame becomes about 1900 x 1900 due to the screw tensioner length, calibrated springs etc.

This should be reduced by bringing the edge of the tensioning member to the edge of the 1200 x 1200 sample and leaving a working space of approx 150mm per side.

The overall space within the frame therefore should be about 1500 x 1500mm.

4. MACHINE DESIGN LOADS

Assuming a working section of 600 x 600mm and a tensile strength of fabric ranging up to 150 KN/m, the force required to break the sample is 90 KN (9 tonnes).

Allowing for high test samples, and a tensioned width of 900mm (600 working section) the force required is 160 KN (16 tonnes).

To reduce the bending moments on the frame members, the load would be better applied at two points giving a load of 80 KN (8 tonnes) on each point.

5. LOADING MECHANISM

The magnitude of the loads required poses two questions:

- Sensitivity of Measurement at low loads?
- Mechanical, Hydraulic or Pneumatic load actuator?

If we are trying to measure prestress stretch at say 3-5 KN/m and break loads at 150 KN/m, the range is over 30:1.

Load Measurement with the same mechanism at low loads would involve considerable inaccuracy.

Two Stage Loading

The problem calls for a low load actuator at up to 20 KN/m, and then high load actuators above that level.

Actuator Type

Hydraulics would appear the simpler and lower cost solution with ready load measurement capacity and ability to equalize on both sides of the frame.

Two 10T actuators (pull type) and a single stage 5T actuator would be mounted on each side of the frame.

Hydraulic pumps with diversion valves for the Warp & Weft direction loadings would also be necessary, plus accurate drag pressure gauges, which would be accurately calibrated.

The ability of the machine to measure extension by graph recording sensors would also be desirable, although direct measurement on a set grid would probably be more reliable.

6. CREEP TESTING

The most common loading of a tension structure is achieved by tensioning to a preset position (turnbuckle length or hole position) and perhaps a measured loading.

After that, the fabric creeps over life between fixed geometry points.

This can be simulated by having screw adjustors on the loading frame to lock the tensioned specimen in place at a preset tension.

Periodically the actuators can load the fabric and determine the prestress level at which the fabric "lifts off" the adjustors.

This could effectively measure exact creep in terms of loss of load between fixed geometry.

This is somewhat different to conventional creep testing which fixes the load and measures the extension, rather than fixing the extension and measuring the load.

Of course, conventional creep measurement can also be made by maintaining the load by constant hydraulic pressure.

7. ADDITIONAL CAPABILITY

With such a tester, investigation of dynamic tear performance could be made.

The most likely damage event is the penetration of the membrane while under high loads. Cuts could be made and tear propogation checked up to any desired level of biaxial stress.

8. CONCLUSION

Detail design is proceeding for construction of a tester as described in this paper and test results should be available for industry use within the next 6 months.