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LOADING RATE EFFECTS ON FOAM CORES FOR MARINE SANDWICH STRUCTURES

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Abstract This paper presents first results from a project which aims to generate foam core properties under loading rates representative of those encountered during wave impact of racing yachts. First, special instrumentation enabled shear strain rates to be measured in-situ. Then a symmetrical shear test was designed to allow shear stress-strain behaviour to be determined at rates corresponding to those measured at sea. Image analysis was used to validate the test set-up. First results for high density foams indicate that quasi-static data may suffice for design.

Keywords Foam core, PVC, high rate, shear, instrumentation.

1. INTRODUCTION

Foam cores are widely used in the sandwich structures used for boat construction. These materials provide weight gains are often preferred to honeycomb cores in areas likely to encounter wave impacts. The selection of foam type and density is generally based on quasi-static design data but the loading rates can be very high in these regions. It is therefore of considerable interest to develop tests which enable properties to be determined at rates corresponding to service loading conditions. Several previous studies have addressed this subject and some data are available [1-4] but the development of new foam grades makes it difficult to compare these data.

The aim of the work described in this paper is threefold. First, measurements on a racing yacht using special shear strain plugs enabled strain rates to be measured. Then a test was designed to enable shear tests to be performed at these rates. Finally data was generated and the test procedure was validated using image analysis.

2. SHEAR STRAIN MEASUREMENTS IN-SITU

Special instrumentation was designed and built in order to evaluate the strain rate levels encountered in a sandwich hull loaded under slamming conditions, Figure 1. A similar system has been used on pressure-loaded panels previously [5].

Strain gages are intrusive, and to assess this point, a calibration of strain levels has been performed in the laboratory using standard shear tests on the foam. A ratio of 2.37 was found between the mean strain level and that measured with the shear strain plug.

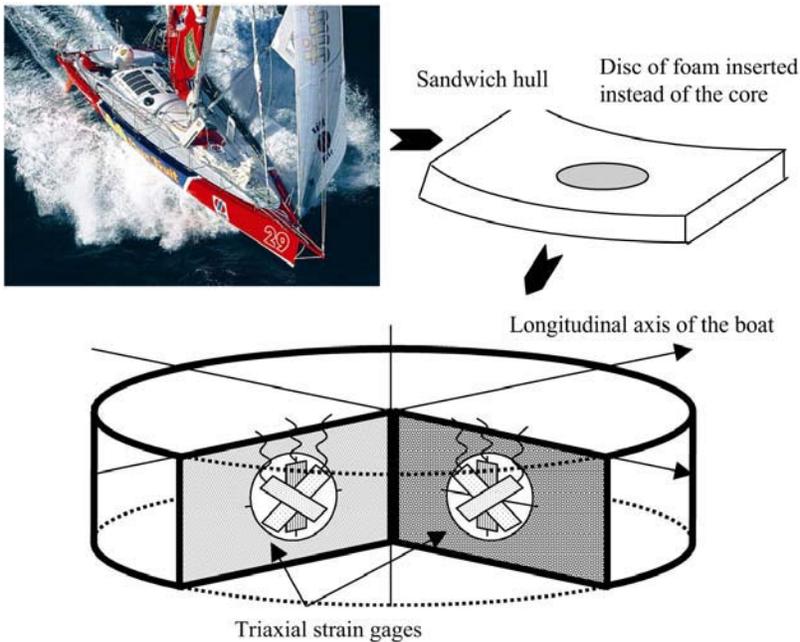


Figure 1. Instrumentation plugs used to measure core strains in-situ.

This ratio was used subsequently, when identical plugs were mounted on the racing yacht shown in Figure 1. Figure 2 shows an example of the data recorded.

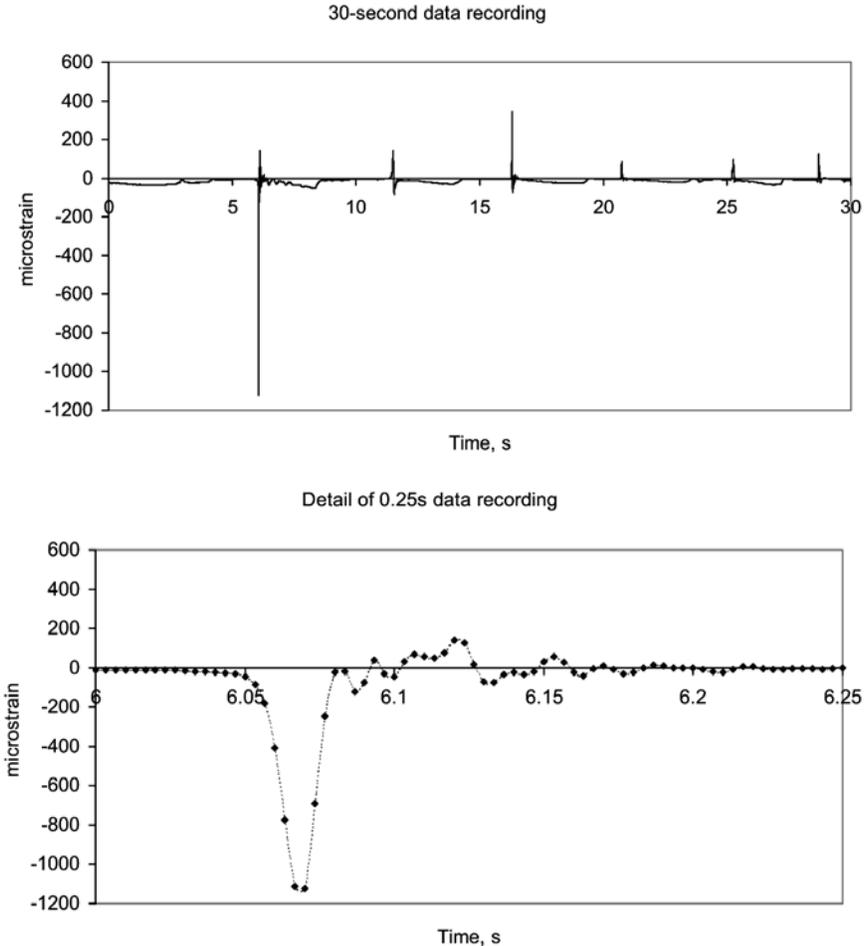


Figure 2. Example of longitudinal shear strain measurements recorded at sea. Upper: 30 second recording, Lower: detail of 0.25 second recording.

Based on recordings such as these, core shear strain rates in the range 10-15%/second were measured. This does not mean that higher rates do not occur but it gives a first indication of the loading rate required for tests to compare different materials. This rate is not excessively high and can be easily achieved with standard hydraulic test machines provided a uniform

strain field can be generated. In this initial part of the project emphasis was placed on shear tests.

3. SHEAR TEST

The shear properties of foams are usually determined by standard tests such as ASTM C273, NF T 54-605, Figure 3. The main disadvantage of these tests for high rate loading is the rotating links.

In order to minimize inertia effects during high rate loading a rigid symmetrical fixture was designed, Figure 4.

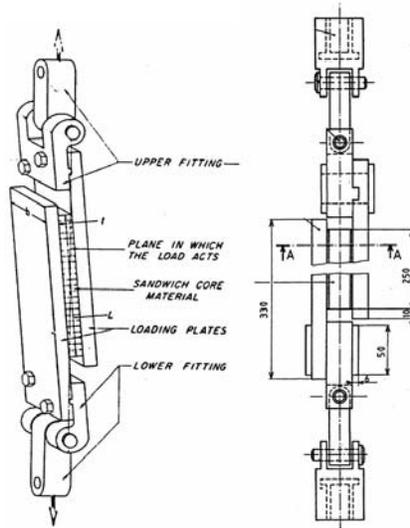


Figure 3. Standard shear test fixtures.

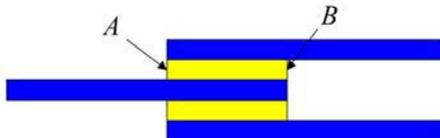


Figure 4. Double rail shear specimen.

This configuration is easy to test but results in high stress gradients at points A and B. In order to limit these stress gradients, which increase as the specimen thickness increases, the fixture was modelled using SAMCEF[®] software. After a series of iterations the final test fixture is shown in Figure 5. The central support is made from aluminium alloy in order to reduce inertia, the outer supports are steel and are linked in order to make the structure rigid and avoid transverse movements. The specimen thickness is that of the panels used, width is 50mm and length is between 150 and 250 mm.

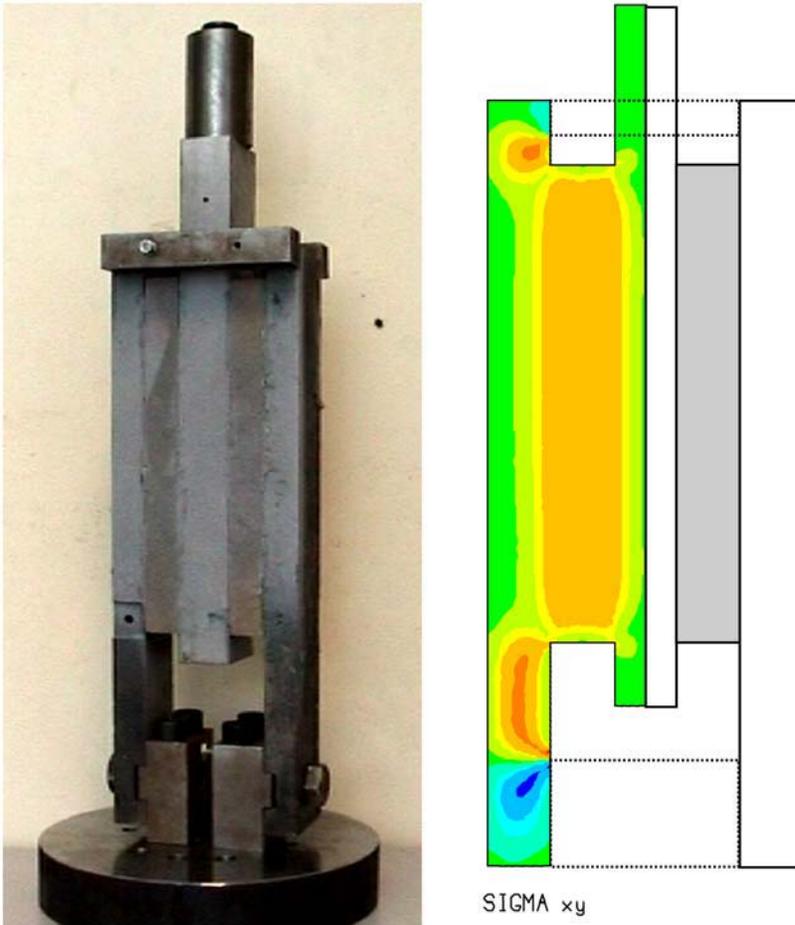


Figure 5. Test fixture and shear stress distribution.

FE modelling of this fixture shows a reasonably uniform shear stress field, Figure 5. If we consider the variation in stresses σ_{xx} and σ_{yy} along the specimen length they vary at the specimen ends, as for the standard test

specimens, which leads to failure initiation there. This results in an under-estimation of the non-linear behaviour, but has no influence on the elastic response.

4. TEST PROCEDURE & MATERIALS

The fixture is mounted on a tensile test machine. The outer supports are fixed to the machine base. The central rail is displaced at a constant rate. An inductive transducer measures the relative movement of the inner and outer rails and a load cell measures the force.

The foams tested were PVC foams supplied by Airex as 20mm thick panels. Results from tests on Herex C 70 200 foam will be presented here. The supplier’s data values, used in the FE analyses, are shown in Table 1.

Table 1. Foam properties (supplier data).

Property	Herex C 70 200
Compressive modulus (MPa)	260
Tensile modulus (MPa)	180
Shear modulus (MPa)	75
Density (kg/m ³)	200

First validation tests were performed at a loading rate of 1mm/min. The foam was bonded to the rails using a *Redux 420* epoxy adhesive. These tests indicated a shear modulus of 85 MPa.

In order to remain within the load limits of the test machine (100 kN) the length of the specimen was reduced from 250 to 150mm. This results in a shorter uniform stress region and may invalidate the test, so an FE analysis was performed in order to establish the uniformity of local stresses in the region used for global modulus measurements, Figure 6. For the 150mm length specimen, the error in the shear modulus is estimated at 5%. It was therefore decided to used full strain field measurements, giving local strain measurements, to determine the shear response. Black paint spots sprayed onto a white background layer were used, with image analysis software. An example of the results from preliminary tests is shown in Figure 7. This showed clearly that with one of the early fixtures there was a tendency for the lower part of the fixture to close up during the test. The lower fixing

bolts were under-dimensioned, a subsequent fixture modification eliminated this effect.

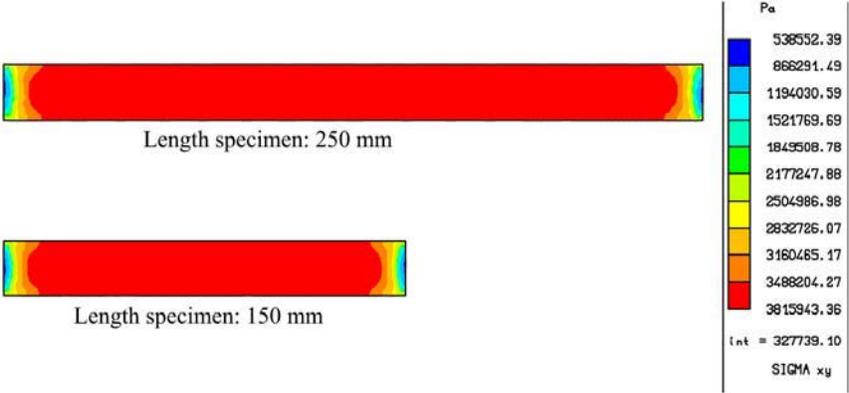


Figure 6. Shear stress distributions, two specimen lengths.

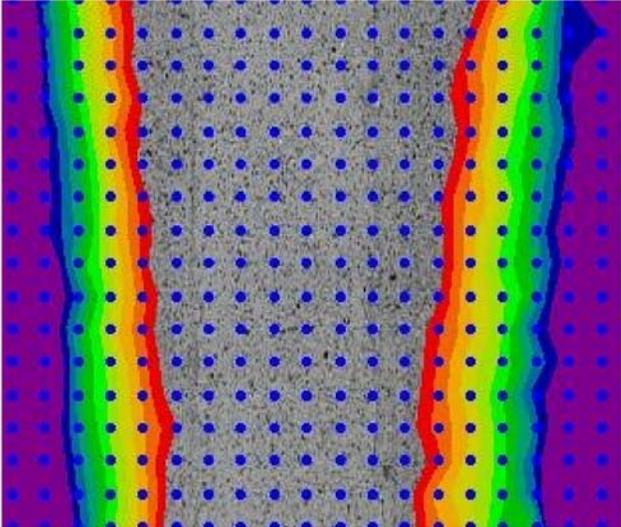


Figure 7. Example of image of test with early fixture.

Following those initial static validation tests the influence of loading rate was examined. Some first results are shown below.

5. RESULTS

Tests were performed at three loading rates which are faster than the rates measured at sea. Figure 8 shows the global behaviour laws for the three rates. It is interesting to note that for this rigid 200 kg/m^3 density material, no significant influence of loading rate is observed, at least up to 5% strain. This is in contrast to previous results reported for lighter foams. The shear moduli values measured are all in the range 85-90 MPa, compared to the value of 85 MPa measured in the test at 1 mm/minute.

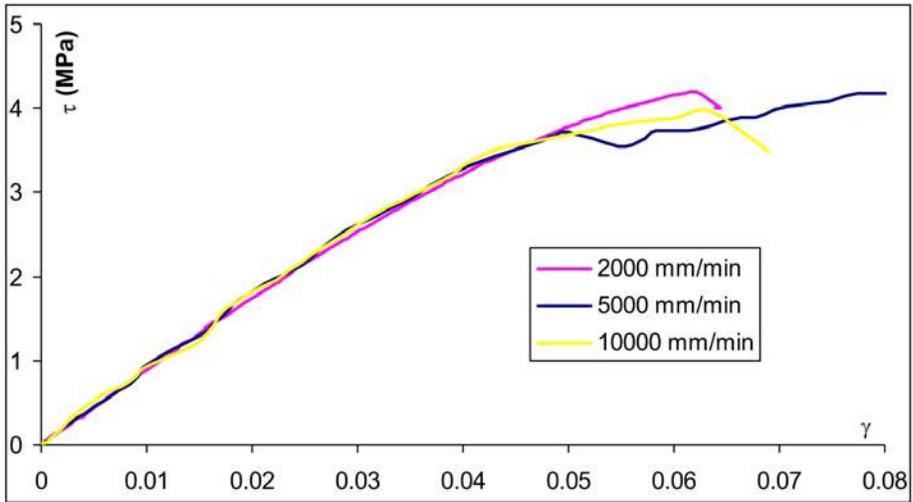


Figure 8. Shear stress-shear strain curves for three loading rates.

6. CONCLUSIONS

The aim of this project is to establish the appropriate foam properties to be used in the design of racing yachts and other vessels which are subjected to wave impact loads. Measurements at sea have identified the loading rates for one type of craft under certain sea conditions. A test fixture has been developed and validated using FE analysis and full strain field measurements in order to achieve these (and higher) loading rates. First tests results indicate that quasi-static data may suffice for high density rigid foams. Further work is underway to study lighter foams, other core materials and higher loading rates.

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