

TESTS ON THE NAVAL BRIDGE COMPOSITE MATERIALS

ELENA-FELICIA BEZNEA, IONEL CHIRICA, RALUCA CHIRICA

University “DUNAREA DE JOS” of Galati, Romania

Abstract: In the paper, a study on the buckling analysis of the naval bridge plate specimens made of composite materials instead of steel for the structure is treated. The advantages of using composite materials for the structure of the bridge is made so on the strength and stiffness and for the other reasons. A study on, made of composite materials is presented. Certain bridge plate specimens, of various thicknesses, so in the case of perfect manufacturing and in the case of existing imperfections were analysed. In this paper, only the case of perfect manufacturing specimen is presented.

Keywords: composite materials, buckling, naval bridge structures, tests

1. INTRODUCTION

The design of any composite structure depends strongly on the fabrication methods. It is not always feasible to fabricate the optimum design configuration. It is very important for a designer to know the state of the art of the fabrication. Composite structures are increasingly being considered and used for lightweight, advanced applications, in areas with high corrosion, and in areas requiring the integration of the structure with other ship systems.

When composite materials are chosen for naval bridge structures, it is generally because they can offer properties, which are particularly attractive for that specific application. In case of composite structures, many materials show nonlinear stress-strain relationships and lamina strength may dominate the ultimate strength especially after lateral deflection grows by buckling when the panel has a laminate structure. Such behaviour is quite different from metal structures.

An experimental study on buckling analysis of the column specimen, made of composite materials is presented. The plate specimen (column), so in the case of perfect manufacturing was analyzed. Nowadays, designs of structures are submitted to routines of optimization in order to reduce the weight and the cost of structures.

Mechanical studies, reductions of frames, use of high strength materials are commonly used. However, those optimizations leads to increase the stress in frames, and hazards of instability has buckling is increased.

Buckling is a sudden bend of structure under compression. As every instability phenomenon, buckling mechanism is influences by geometrical imperfections, loads imperfection and randomness of material properties. Many papers can be found on internet. The analysis of imperfection sensitiveness has attracted the attention of many engineers in the past decades due to the crucial role that imperfections play in the buckling and post buckling behaviour of shell structures.

Moreover, the rapidly increasing use of high-performance composite materials in the fabrication of structural components and systems has provided the motivation for a vigorous and sustained research in this field. The behaviour of composite structures differs from that of metallic one in several aspects. The former are

heterogeneous and anisotropic and are considerably more shear deformable than the latter, and possess distinctive failure mechanisms.

The objective is to draw behaviour curves for composite plate and to explain theory and experimental process.

In linear mechanism of deformable bodies, displacements are proportional to loads (load displacement curve is linear). Buckling, however, is a disproportionate increase in displacement resulting from a small increase in load (the load-displacement curve do not follow a line). Consequently, buckling analysis is a subtopic of nonlinear rather than linear mechanics.

2. EXPERIMENTAL STUDY

2.1 Material used for the experiments

For the experiment, an epoxy resin and 0/90° E-glass fibre woven roving are used. E-glass means Electrical fibre, called as it due its treatment. This fibre has lower alkali content and is stronger than A glass (alkali). Its surface carries net electrical charge of opposite sign to create a sustained adhesive force with the resin. Its properties are a good tensile, a good compressive strength and stiffness, a good electrical properties and a relatively low cost.

However, the impact resistance is relatively poor. E-glass is the most common form of reinforcing fibre used in polymer matrix composites. The E-glass fibre used is from SP System; reference WOVEN 2x2 Twill EGL WRE 581T/1250, which means a woven fabric of 581gr/m². Woven fabrics are produced by the interlacing of warp (0°) fibres and weft (90°) fibres in a regular pattern or weave style. The fabric's integrity is maintained by the mechanical interlocking of the fibres.

2.2. Tests on the test machine

2.2.1. Tests

For every case of thickness, three equal plates will be examined. If there is important difference of buckling load, then a test on 5 samples were conducted. Every incoherent result will be moved out. Incoherent results are samples offering more than 20% of relative error with the "apparent" mean.

The kind of boundary conditions examined was plates with both clamped ends.

2.2.2. Presentation of the test machine and of the software used.

The loads and displacements were collected by a computerized data acquisition system. For each column, the test was terminated when the first buckling mode was reached. The machine used is an INSTRON electro-mechanical test frame and offers two load cells: 2 KN and 50 KN. The cell used goes up to 50 KN because thicker sample should buckle around to 3.5 KN. The press is activated by a software called BlueHill. It permits to set up transducer limits, calibrate and balance transducers, and set up the console live displays.

To keep the sample usable for a second test, only a displacement range of 5 mm in compression is allowed, therefore the sample are still in their elastic domain. In compression, a crucial parameter is the gain. Also called "loop shaping", the user's manual says that "it tunes the control loop so that the movements of the crosshead closely follows requirement of the command signal from the controller. This tuning reduces any tendency for crosshead motion to lag behind or to overshoot". The gain is set according the stiffness of the sample. For this, a traction test in the elastic domain is conducted; note the delta of displacement and the delta of load.

2.2.3. Young's modulus determination

It is possible to calculate properties knowing the volume of fibre. However, it is not possible to have accurate answer due to delaminating phenomenon when the volume of resin is to low. The best method is still to do

calculation on Young's modulus by tension test. For that, the test machine is set at a load rate of 1 mm/min and some samples are produced.

A first set of sample 150 x 15 mm, with aluminium end plate were used, but the young's modulus obtained were not correct. Longer sample were build to reduce the error by allowing more displacement for the same load: 300 x 15 mm (Fig. 1). In figure 1 the traction test sample and rig are presented.

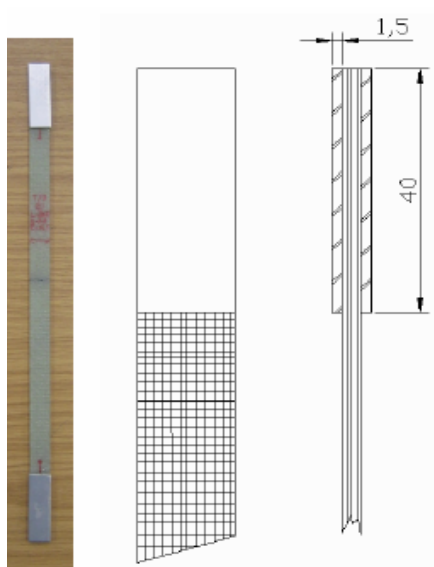


Fig. 1

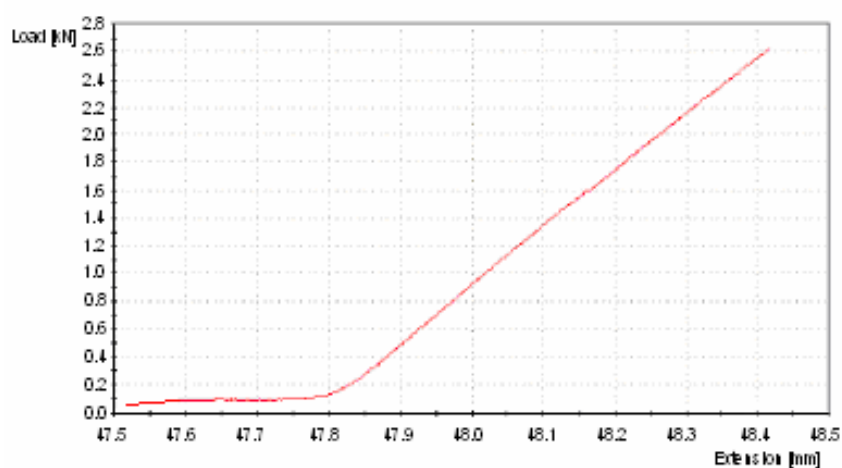


Fig. 2

To obtain experimental error 3 samples for each laminate were produced and tested. To find the Young's modulus, the stress against the strain is plotted (Fig. 2), calculated from the load/extension curved given by the test machine acquisition software. Note that the step on the graph 2 is due to the play of the rig, happening at 120N, corresponding to the 12Kg of the grips. In figure 3 the curve σ - ε is plotted, to have the trend line equations of the linear parts. In the elastic domain, for a specimen of initial length l_0 , final length l and sectional area A , loaded by force F , the Hooke's law is

$$\sigma = E \cdot \varepsilon \quad (1)$$

with

$$\sigma = \frac{F}{A}; \quad \varepsilon = \frac{l - l_0}{l_0} \quad (2)$$

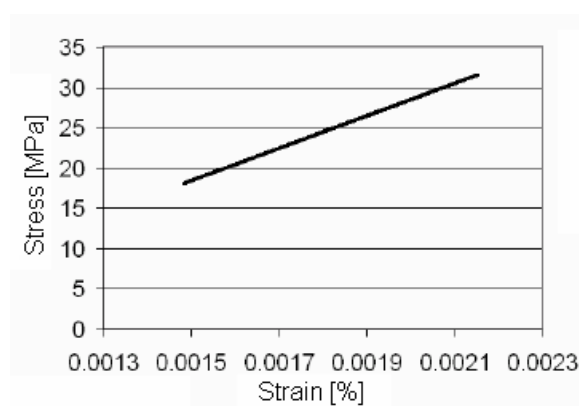


Fig. 3

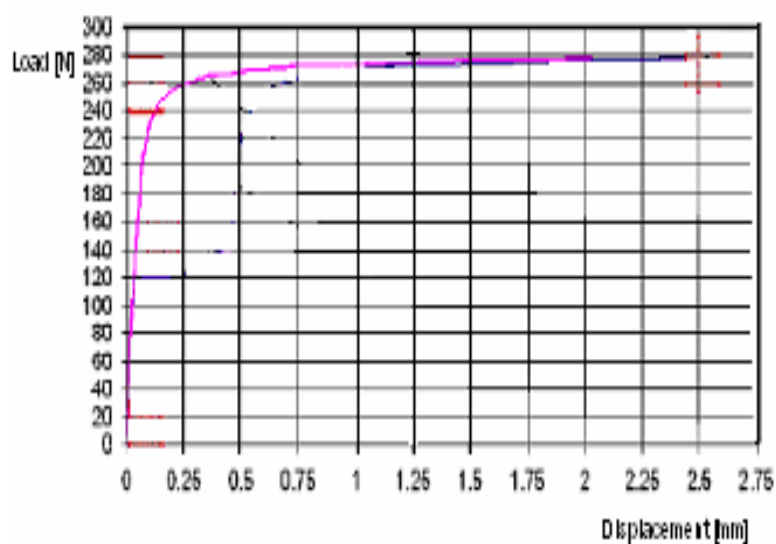


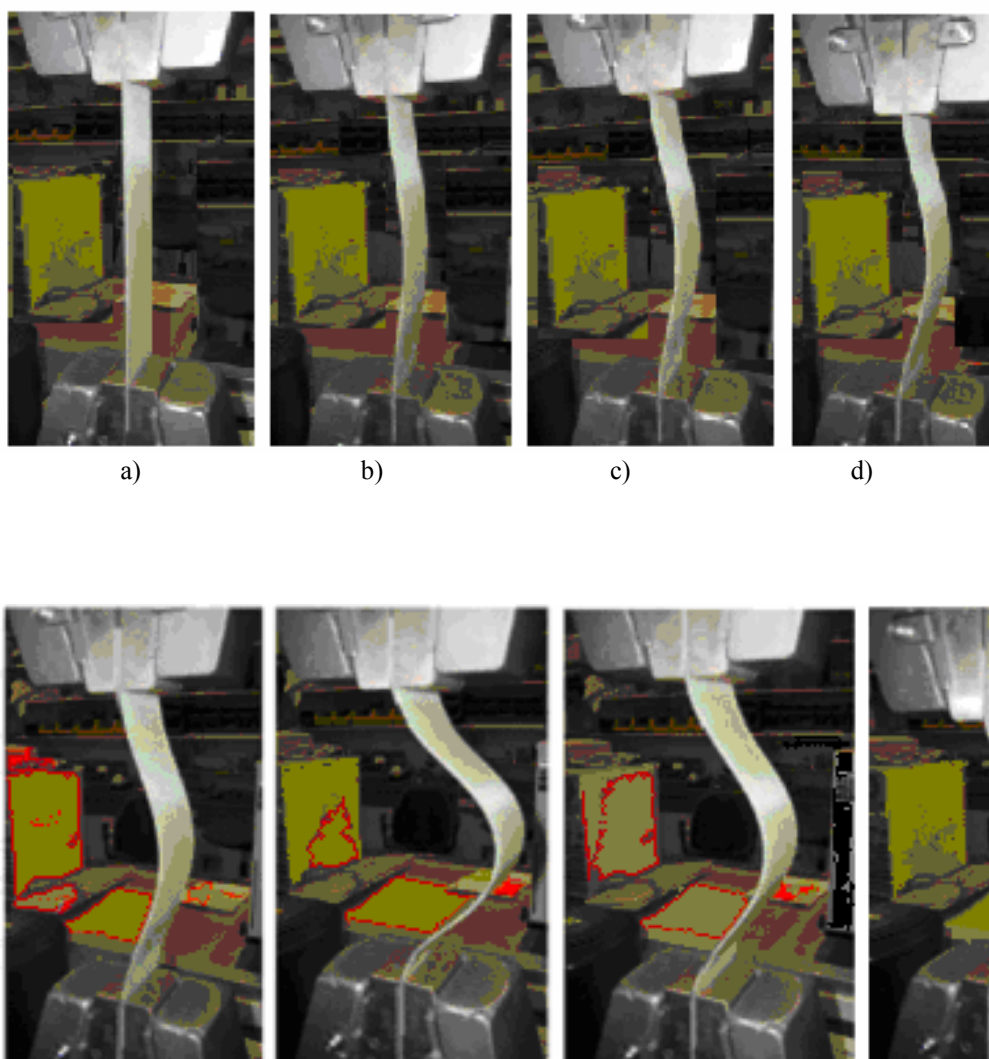
Fig. 4

2.2.4. Buckling diagram

During the test, a diagram was plotted. For the clamped/clamped conditions, results are acceptable. The load-displacement curve is presented in figure 4. Initial it has an offset to apply, due to the play of the grips. This source of error is demonstrated by the load value where the curve takes its original shape: 120N, exactly the weight of the grip.

2.2.5. Phases of the test

In fig. 5 the following phases of the test are presented: compression (figure a), initiation of buckling: bending (figures b, c and d), bending (figures e, f and g), sagging (figure h).



3. REMARKS

It was found that the experimental test results conformed to the theory. Only a difference on maximum buckling load is different from the theory. The experimental results were compared with the Finite Element Analysis results. The FEA results follows the mechanical buckling behaviour, however there are still mismatches with the experimental results.

It was found that FEA under predict the buckling load. Moreover, theoretical formulations overpredict the buckling for thin plates (3 plies), are good approximation for medium plates (6 plies) and underpredict the buckling of thick plates (10 plies).

The paper has been prepared within the project MARSTRUCT–Network of Excellence on Marine Structures, which has been funded by the European Union through the Growth program No. TNE3-CT-2003-506141 (www.mar.ist.utl.pt/marstruct/). The tests have made within the Task 4.3 of the Project.

REFERENCES

- [1] Jones, R.M., *Mechanics of Composite Materials*, Taylor & Francis, Philadelphia, 1999.
- [2] Whitney, J.M., *Composite Materials, Testing and design* (7-th Conference, 2-4 April 1984, Philadelphia, ASTM.
- [3] *** **Report of Committee IV.2-Design Methods**, Proceeding of 16-th I.S.S.C., 20-25 August 2006, Univ. of Southampton, page 609-686, 2006.