Incorporation of Research and Novel Teaching Ideas into the Unit 'Surf equipment, design, materials and construction'

Audy J.* & K., and Haines T.

Edith Cowan University
School of Enterprise and Technology
Faculty of Regional Professional Studies
South West Campus Bunbury
Australia 6230
E-mail (*Corresponding author): j.audy@ecu.edu.au

Dr. Jaromir AUDY is a Lecturer in Materials Science in the Surf Science and Technology at Edith Cowan University. His professional experience is in design, development of prototypes and testing, analyses of ferrous, nonferrous materials, composites and testing, and production methods such as laminating, casting, forming, forging, machining. Teaching and Research interests include: materials involved in surfing, boating and automotive industry, optimisation of manufacturing methods using data banks and computer assisted predictions.

Dr. Katarina AUDY is an active researcher and lecturer, currently working on two teaching and learning grants at Edith Cowan University. Her professional experience is in materials, testing, manufacturing processes, and data analysing. Research interest includes: reconstruction and restoration of historical buildings and ancient artefacts, archaeological metallurgy, and corrosion and degradation of materials.

Mr. Terry HAINES, formerly the Head of School of Enterprise and Technology, is Acting Associate Dean (Teaching and Learning), Lecturer in IT and computer science, and a full time employee of Edith Cowan University. Terry's background is in computers, modelling and data analysing.

Incorporation of Research and Novel Teaching Ideas into the Unit ‘Surf equipment, design, materials and construction’

Abstract: There are four aspects of this paper which deal with the “Theoretic Underpinning of Innovative Practices in Teaching, Learning and Research” within the Surf Science and Technology Program at ECU. These are Experimentation and Testing on Real-Life Damages of Surfing Equipment, Improvisation, Individuality of Learning environment, and Dissemination of results and conclusions. Experimentation and testing was conducted on real-life damage of surf equipment. Improvisation was necessary due to limited resources and lack of access to commercial professional testing equipment. Students had to think laterally to make use of available resources to create testing situation where were both reliable and accurate. Individual Teaching and Learning Environment involved a number of damage surf boards that were obtained from commercial surf board manufacturers and/or individuals. Students selected a damaged surf board and had to devise a test and facility to carry out experiments from available resources. Although these units were taught there was no focus on testing the real surfboards the results and conclusions have remained within the unit. In 2004 the students were able to use their own results and the results of other students and incorporate these results into the design and manufacture of their own surfboard within other units taken concurrently with the unit. This is the first stage of dissemination of results. Moreover, for the first time this semester the teaching was focussed on examining flexural and impact behaviour of various surfboard construction panels and appears to be successful from both teaching and research point of view. Because in this relatively new academic discipline there are limited relevant professional journals specifically related to Surf Science and Technology this paper is one way of disseminating the results and conclusions to a wider audience.

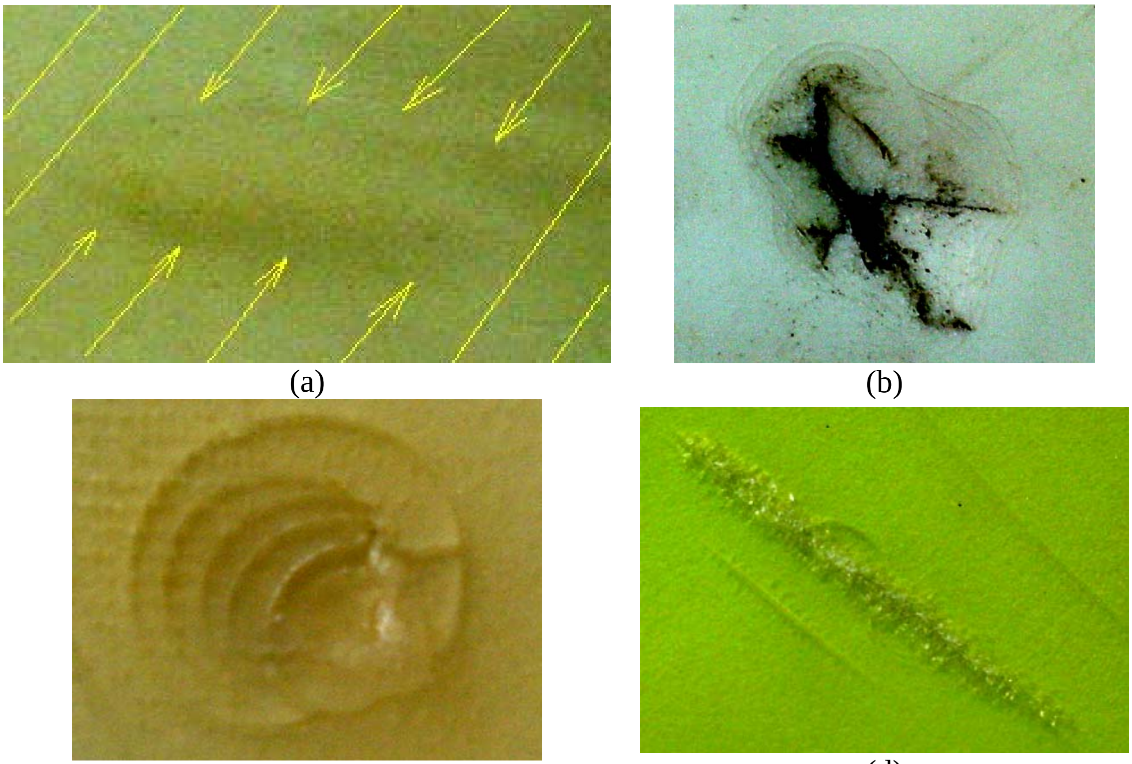
Keywords: Surfboards, Breaking Mechanism, Failure, Laminates, Polyurethane Foams

1. Surfboard Materials and Breaking Modes: An Introduction

Commercial surfboards are made from lightweight sandwich structures [1 to 5]. These structures are made of a core laminated in fibreglass [1 to 3]. The core is made of polyurethane foam strengthened in the middle with a wooden stringer to improve stiffness [1 and 4]. The polyurethane foam is a soft and light weight material [1 to 5]. Its density is low ~40kg/m^3 [3]. This means that the blanks used for shaping the surfboards are very light [1 and 4]. Their masses vary from about 2.5 kg for small blanks to about 4.5 kg for large blanks [1 and 4]. After shaping they lose ~30% of their volume and when laminated the dry area weight of fibreglass is some of ~200g/m^2 [3].

In seeking improved surfboard performance, the surfboard manufacturers and users made significant advances through the modifications of surfboard geometry [1 to 4] and the use of advanced materials [1 to 4] for sandwich panels [3] and laminates [3] employed in surfboard construction. Most recent developments in the surfboard industry relate to the decrease in surfboard weight [1 to 5] by reducing the thickness of both the polyurethane cores for boards [1, 4 and 5] and polyester resin / E-glass woven fabric for laminate skins [1, 4 and 5]. As a result these minimum weight and thickness boards have a limited service life time [5] due to their inability to deal with impact damage from waves. Moreover, they suffer severe cosmetic problems [2], caused by impact damage from the human body and rocks. Some most common types of damage are documented in Figure 1 (a to d). Figure 1 (a) shows smooth compression dents from various human body parts typically the head and knees. Further details in Figure 1 depict: jagged cuts (b), compression cuts (c) and scratches (d) as a result of impact with rocks.

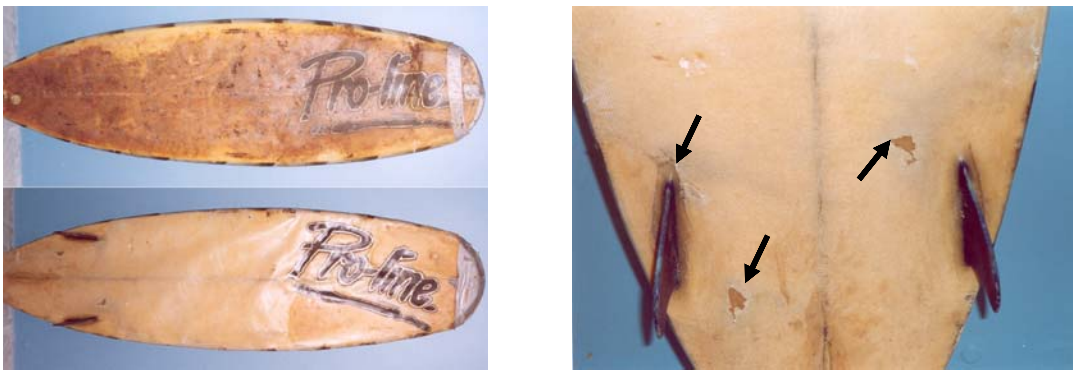
The types of damage from rocks are particularly unpleasant because they tear the laminate and damage the foam, see Figure 1 (b), or create cracks, see Figure 1 (c) and (d), through which the salt water is able to penetrate and cause delamination of the laminate from the polyurethane foam.



(a) (b) (c) (d)

Figure 1 Photographs showing several types of damage on surfboards caused by the head and knees (a) and rocks (b to d).

Typical damage from delamination is shown in Figure 2 (a to d). The photographs were taken from a surfboard that was found lying on a beach and donated for research purposes by one of our surf science student. Figure 2 (a) depicts the surfboard in ‘as found’ condition. Figure 2 (b) shows the extent of damages (holes in the laminate) around the fins. Figure 2 (c) shows the nose that was once broken, cut, rounded and not professionally laminated. Because of this salt water was allowed to penetrate though the holes, scratches and cavities, causing a complete delamination of the laminate and damage of the polyurethane foam as shown in Figure 2 (d).



(a) (b)

Figure 2 Photographs showing an old fashioned surfboard that was left abandoned on a beach (a), damage of laminate around the fins (b), and laminate stripped from polyurethane foam – bottom side (c), and deck (d).

(c)
foam, left, laminate skin, right

(d)
foam, left, laminate skin, right

Figure 2 Continued from previous page

The damages shown earlier in Figures 1 and 2 affect both the appearance and material properties but the surfboards can still be used. The most severe bending damage to surfboards occurs as a result of collisions with the wave. Table 1 shows a set of photographs and relevant details associated with breaking damage of four different commercial surfboards (A to D). The first three boards (A to C) were short ones (6’0’’ and 6’1’’ in length) and quite light ones (weighing less than 3kg). They all were new and purchased for more than $400 and less than $500. Board D was long (6’6’’ in length), weighed 3.8kg with fins, and being old was purchased for about $80. Board A had its nose broken when it dived into the sand. Boards B and D snapped under bending impact from a wave. Board C snapped when the surfer hit a reef. The age of these boards apparently did not play a significant role in life reduction since board B was only 3 months old when snapped by a wave when floating on water.

Table 1 Photographs showing fatal damage of four different commercial surfboards, left, and their relevant details, right.

	**(A)** 6’0’’ x 18 $^{1}/_{4}$’’ x 2 $^{1}/_{4}$’’ by Green Deluxe (~$400 new) weight without fins 2.8kg about 2 years old when damaged by the nose diving into the sand used daily (2 times a day)
	**(B)** 6’1’’ x 18 $^{3}/_{8}$’’ x 2 $^{1}/_{4}$’’ by Damien BIBIC (~$430 brand new) weight with FCS fins 3.1kg about 3 months old when damaged by a wave when floating on water used daily (2 times a day)

Table 1 Continued from previous page

	**(C)** 6’1’’ x 18 $^{3}/_{4}$’’ x 2 $^{3}/_{16}$’’ by Boyd Purdy YALLINGUP (~$500 brand new) weight without fins 2.4 kg 6 months old when snapped. Nose hit a reef and the board snapped under the weight of the surfer
	**(D)** 6’6’’ x 18 $^{1}/_{2}$’’ x 2 $^{3}/_{8}$’’ by Dale Chapman weight with fins 3.8 kg Very old Board (~1990) (purchased for ~$80, about 2 years ago) Used occasionally, Snapped by a wave

The observation of these surfboards illustrated in Table 1 indicated that the failure was probably initiated by the wrinkling on the side of the board that was actually under compression when hit by a wave. Board C, for example, exhibited significant wrinkling on its bottom side which was its compression side when the board was flexed by the weight of a surfer standing on its tail after the nose hit the reef. Figure 3 shows two photographs: the one on the left picturing a surfboard with compression wrinkles across the laminate, and the one on the right picturing a section of a surfboard that snapped under flexural bending.

Figure 3 Photographs showing compression wrinkles across the laminate on the bottom side of a surfboard, left, and clear snapped failure due to flexural bending impact.

An inspection of broken surfboards indicated that they failed by compression of the foam core induced by localised wrinkling of the laminate due to bending and / or impact load. This observation is in agreement with experimental results published by Manning *et al* in paper [2] who suggested that it is possible to study the flexural behaviour of a surfboard using the four point bend test, (described in source [6]), which is able to produce stresses similar to that experienced in reality.

To date little information has been published on sandwich construction panels [1 to 3 and 7 to 9] and their breaking mechanism in terms of flexural bending and impact behaviour. The reported information in source [1] was mostly descriptive and only a few sources [2 and 3] provided very limited data needed for quantitative study of surfboards as a whole. Consequently, the present investigations were set up to study, in laboratory conditions, flexural bending of sandwich panels and impact damage of laminates in order to get the results similar to those exhibited by surfboards broken in service conditions.

In terms of pedagogy the students were able to make use of real damaged surfboards and employ problem solving techniques to determine laboratory tests that would be both reliable and valid. Since there were a variety of surfboards with different damage the students were required to individually determine a valid and reliable test. Moreover, their own results and those of other students were applied during the design and manufacture of their own surfboard. Each student designed and manufactured his or her own surfboard and / or a body board in another unit done concurrently lectured by the same lecturer.

The following experiments were a part of laboratory work conducted by the first year surf science students in the second semester of 2004. The group of students was quite small. It consisted of 14 people, namely 5 males and 9 females. Two students were international (one from England, one from the United States), while the other twelve students were Australians. The majority of students (~80%) came from 'small' country towns, whereas others (20%) were either from private or top government High Schools.

Those students who lived in the country where technology and education were not at an advanced stage in comparison to larger cities found it difficult to adapt to University requirements in terms of bridging the differences between the study load at High Schools and University. Most of the 'regional' students experienced major difficulties of understanding the basic mathematical terms and equations. Because of this, the majority of such students find it hard to understand technical terminology and scientific approaches used in lectures and tutorials associated with 'Surf Equipment, Design, Materials and Construction' courses.

During lectures and tutorials some students tended to be quiet, probably due to the fear of being judged by their 'more skilled' colleagues, and it appeared that even with the lecture notes and literature materials, they still had difficulty in understanding the topic in greater detail. From experience it has been recognised that there is a need to improve lecturer/student communication, to encourage interaction within the class, to improve students' self-confidence and method of teaching and learning styles for better understanding of the subject. With those aims in mind the laboratory experiments were designed to address the following attributes: professional knowledge; workplace experience, enterprise; initiative and creativity; service; problem solving/decision making; internationalisation / crosscultural awareness and communication. The major focus was on conceptualising the material delivered in class rooms and providing a link between theory and practice. It was done by simplifying the lecture material to simpler cases and linking them to students' personal experiences. This approach provided a number of samples and case studies for assisting the SST students to realize how to apply theory to real life situations.

2. Experimental Details

For the purpose of this investigation five specimens were studied, namely, (1) surfboard C and (2) surfboard D shown earlier in Table 1, (3) non reinforced and non laminated polyurethane foam, (4) polyurethane foam core with a single layer of laminate on deck and bottom, and (5) polyurethane foam core reinforced with plywood stringer and laminated on deck and bottom. Laminated specimens (2 and 3) had a 190 gsm cloth with the fibre orientation of 90 degrees. Surfboards A and B were in reparable conditions and as such were not selected for destructive tests. The specimens used for testing represented different sections of a surfboard as depicted in Figure 4.

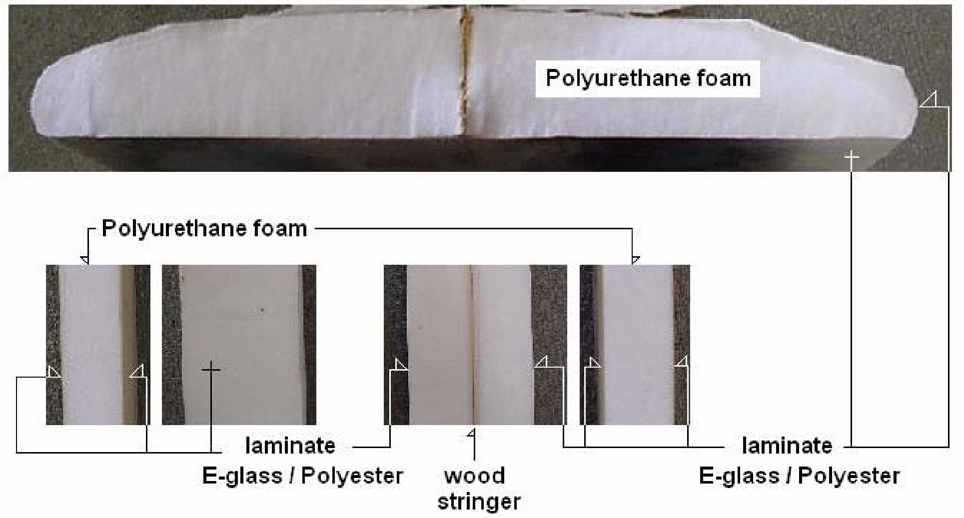


Figure 4 Experimental details associated with the test specimens.

Experimental work was focussed on static (3-point bend) and dynamic (impact) tests. The relevant test arrangement, results and discussion are presented in the following Section 3.

3. Test Arrangement, Results and Discussion

Each laboratory experiment described in sub-Sections 3.1 to 3.3 was designed for the duration of approximately 3 hours. This time limit was set up for preparing the relevant test scenario, conducting experiments and gathering results. It was anticipated that some students with limited hands-on skill and working experience may have a difficulty to transfer theoretical knowledge into practical life. To overcome this problem the students were asked to work in groups. They formed five groups (3 people in a group).

During the laboratory demonstrations students tended to be quite active and inquired about many issues they were uncertain about. Students firstly shared their knowledge together in groups then compared it between the groups. It appeared that there was something like 'an impulsive' competition between the groups in terms of being the first and getting the most reliable results. The role of the lecturer during these sessions was to communicate with the students, help them with the test arrangement, check the results, and most importantly, to provide advice on data analysis, its evaluation and the write-up of the scientific reports. From experience it was recognised that the majority of students lacked the skill in writing technical reports. Those students were in their early course. They were very reluctant to be critical and had a tendency to be descriptive rather than quantitative. The lecturer’s role at this stage was very crucial and an extra consultation time (of ~2 hours per person) was dedicated to go over assignment drafts.

The experimental work, data collection and evaluation were quite straight forward. Students had to follow instructions given to them during the lecture time, and work under supervision of the experienced demonstrator. Some short insides of these kinds related to different tests are briefly shown in the following sub-Sections 3.1 to 3.3.

3. 1 3-point bend Test of a Polyurethane Foam Specimen

Students were encouraged to cut a piece of new surfboard foam, sand it to make a rectangular prism, weigh it and record its dimensions, and calculate its density using Equation 1.

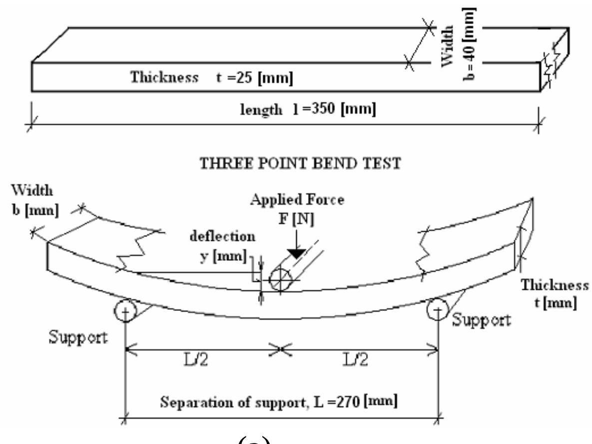
$$\rho[kg/m^3] = \frac{Mass[kg]}{Volume[m^3]} \qquad (1)$$

Table 2 provides an example of some typical results obtained from this exercise. From this table it is evident that the calculated density of experimental polyurethane foam was about 41 kg/m^3, which was similar to the foam density of 40.9 kg/m^3 (st dev=3.5, dof 6) reported for a Type EW219725 polyurethane blank in paper [3].

Table 2 Dimensional, Mass and Density Data associated with experimental polyurethane foam tested.

Thickness t (mm)	Width b (mm)	Length l (mm)	Mass (g)	Volume (mm^2)	Density ρ (kg/m^3)
25	40	350	14.5	350000	41.4

After that students constructed a 3-point bend test apparatus from available materials, and for different loads recorded the deflection of foam specimens. A schematic 3-point bend test and the real experimental arrangement are shown in Figure 5 (a) and (b), respectively.



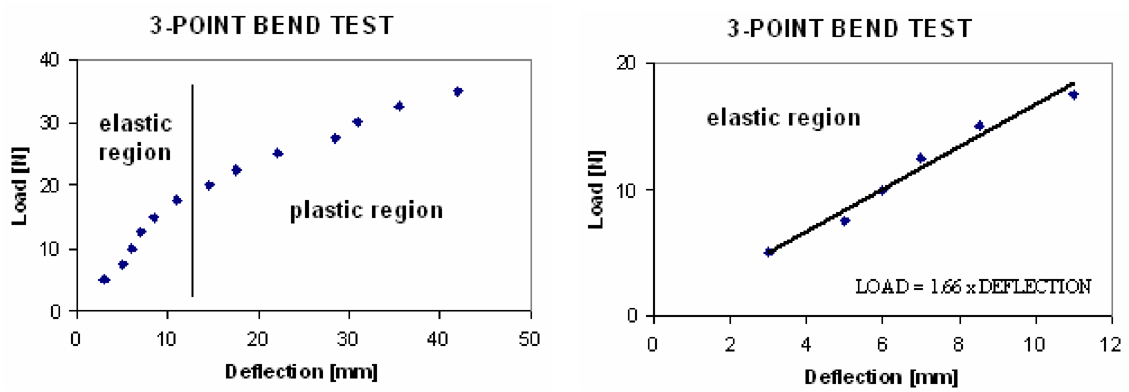
(a)

(b)

Figure 5 Experimental set up for 3-point bend test, left, and the real arrangement, right.

As can be seen from Figure 5 the materials used were from those available, namely, PVC pipes, plastic bag(s) filled up with dry sand to provide the desired weight(s), and tables apart by about 200mm allowing for separation of support of 270mm. This test can be repeated and will produce reliable and valid results. This is an example of students being subjected to an individual learning environment and using problem solving skills to determine the laboratory test. Five groups of students (three people in each group) repeated the test to prove its reliability.

An example of experimental plot of load versus deflection for the foam data, Table 2, and set-up, Figure 5, is shown in Figure 6.



(a) (b)

Figure 6 Experimental plots of load versus deflection data for polyurethane foam prism from Table 2.

From Figure 6 (a) it is evident that the load deflection graph exhibits an elastic region and a plastic region. From data in the elastic region, it was possible to calculate the Young Modulus of Elasticity, *E*. For a rectangular specimen of a width, *b*, a thickness, *t*, and a length, *l*, which is deflected to a distance, *y*, by the applied force, *F*, over the separation of support, *L*, the Elastic Modulus, *E*, is given by Equation 2.

$$E = \frac{F\ L^3}{4\ y\ b\ t^3} \qquad (2)$$

The Equation 2 can be rewritten into Equation 3 that uses the slope of the graph in its linear region. This slope can be determined by using regression analysis and excel software. From Figure 6 (b) it is evident that this slope was 1.66 and regression analysis proved that this slope was statistically significant ($P_{calculated}$=0.00024, $F_{calculated}$=153, dof = 5).

$$E \quad = \quad \frac{L^3}{4\,b\,t^3} \times \text{slope of graph (in N/mm)} \qquad (3)$$

From data in plastic region it was possible to determine the load at failure and to calculate the bending strength, *R*, using Equation 4.

$$R \quad = \quad \frac{3\,F_F\ L}{2\,b\,t^2} \qquad (4)$$

The experimental values were about 12.5 [MPa] for Modulus of Elasticity, *E*, and about 0.54 [MPa] for bending strength, *R*. It may be interesting to note that Wang and Crosky [3] reported that the strength of polyurethane foams may vary by a factor of 2 with respect to variation in cell size of the foam. This would result in having a thinner and stronger panel with better flexural strength and improved ability to deal with elastic stresses from a laminate during head or knee impact. Manning *et al* [2] suggested that the stiffness would be enhanced further by using multiple stringers in surfboard foams.

3. 2 3-point bending Test of Laminated Polyurethane Foams and Surfboards

The flexural 3 point bend tests were carried out using Model AVERY universal testing machine Type 711CCJ located at South West Regional College of TAFE.

This was a rare opportunity for students to see and use prominent testing equipment with experiments directly relevant to surfboards thereby exposing the students to real life of research thinking and industrial testing.

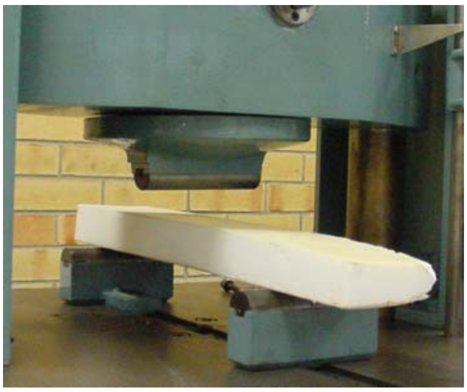
The experimental set up was as follows:

- The span length was 546mm.

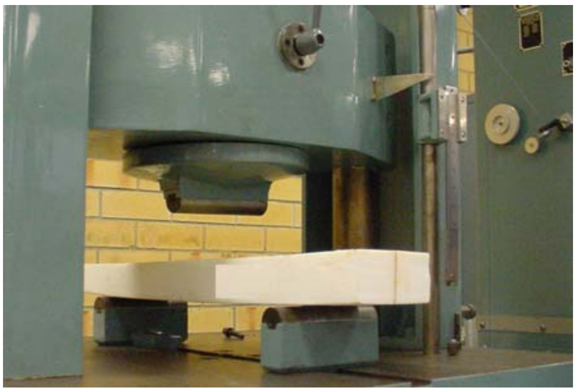
- The radius of rollers was 19mm.

- Laminated specimens were flat parallel faced panels. Their length, width and thickness were 600mm, 115mm and 55mm, respectively. Surfboard C was 56mm thick and 470mm wide. Surfboard D was 51mm thick and 445mm wide.

The experimental test arrangement is shown in Figure 7(a to d). The results are shown in Table 3.



(a) Laminated un-reinforced PU foam



(b) Laminated wood reinforced PU foam

(c) Surfboard C

(d) Surfboard D

Figure 7 3 point bend Experimental test arrangement

Table 3 Results from 3 point bend test

Specimen	Load at peak [N]	Displacement at peak [mm]	Note
Laminated un-reinforced PU foam	650	16	Did not break - failed by delamination of laminate and compression of the core Bending strength R = 1.5MPa
Laminated plywood reinforced PU foam	1830	20.9	Did not break – failed by delamination of laminate and compression of core Bending strength R = 4.3MPa
Surfboard C	2100	22.8	Load at break =1700N Displacement at break = 35.9mm
Surfboard D	2700	31.9	Did not break – failed by delamination of laminate and compression of core

From the results in Table 3 it is evident that the experimental specimens and surfboards failed at loads of between 0.65 kN and 2.7 kN, which is roughly equivalent to weights between 65 kg and 270 kg.

The polyurethane foam strengthened with a plywood stringer had a bending strength greater by a factor of 2.8 (=4.3/1.5) compared to the non reinforced specimen. Manning *et al* [2] reported that the panel which has its core reinforced with much lighter balsa stringer improved an increase in the strength only by about 60% compared to an un-reinforced panel.

Laminated plywood reinforced PU foam specimen was made from recent surfboard blank and its load at peak (1.8kN) and displacement to peak (20.9mm) were identical to those (2.1kN and 22.8mm) obtained from the recent surfboard C. In contrast, surfboard D was about 15 years old and it exhibited more favourable both the load at peak that was higher by a factor of 1.3 (=2.7/2.1) and displacement at break that was higher by a factor of 1.4 (=31.9/22.8) compared to data from surfboard C. This indicates that each surfboard has to be treated individually from material and damage point of view when estimating its material properties and behaviour under stress.

3. 3 Impact Testing of Laminated Specimens and Surfboards

Experimental testing involved the four specimens listed earlier in Table 3. The exercise was carried out by dropping the 7 kg heavy bowling ball from the heights of 1 metre and 2 metres to the surface of each experimental specimen, as shown in Figure 8.

After that students were encouraged to estimate the extent of impact damage to laminate and foam via the measurement of diameter and / or the depth of compression dents.

Again we see students improvising to produce laboratory testing conditions that are able to be repeated producing identical results to make a valid and reliable test scenario.

Figure 8 Some of the 2nd year surf science and technology students involved in impact testing of laminated specimens (Semester 2, 2004)

Generally, two types of compression dents occurred, namely, circular and non circular. Circular dents that reassembled fully the shape of the impact ball were quite rare. In the majority of cases, however, the hole offprints were not symmetrical, mostly because of the delamination of laminate from the compressed foam.

The diameter of the circular compression dents, d, was a function of the diameter of the impact ball, D and the depth of the hole, x, as shown in Equation 5.

$$d = 2.\sqrt{D^2 - (D - x)^2} \quad (5)$$

Whenever the offprints from impact ball were not circular the area, A, was calculated from the 'measured' and 'calculated' values of the diameter of the hole, d_1 and d_2, see Equation 6.

$$A = \frac{\pi}{4} d_1 \, d_2 \quad (6)$$

For a symmetrical hole offprints their relevant volume, V, was calculated using Equation 7.

$$V = \pi \left(D.x^2 - \frac{x^3}{3} \right) \quad (7)$$

For a non-symmetrical hole offprints their "approximate" volume, V^*, was calculated using Equation 8.

$$V^* = \frac{\pi}{4}.d_1.d_2.x \quad (8)$$

Generally, it was assumed that the volume of a dent would represent the work done by the impact ball to damage the specimen. This assumption was based on the following Equations 9 to 15.

Kinetic energy $$KE[J] = M_{IB}.g.H_D \quad (9)$$

where M_{IB} is the mass of an impact ball, H_D is the drop height, and g (=9.81ms^{-2}) is the acceleration due to gravity [10]. Consequently, stress can be calculated from a kinetic energy divided by dent volume.

Stress $$\sigma = \frac{KE}{V} \quad (10)$$

Volume $$V = A.x \quad (11)$$

Work $$W = F.x \quad (12)$$

Stress and Force $$\sigma = \frac{F}{A} \Rightarrow F = \sigma.A \quad (13)$$

From Equations 12 and 13

$$F.x = \sigma.A.x \quad (14)$$

Then the Work $$W = \sigma.V \quad (15)$$

The most important results from impact testing done at two different drop heights of 1m and 2m are depicted in Figure 9. This figure shows the percentage differences in impact energy of different experimental specimens with respect to the laminated but unreinforced specimen which was taken as etalon for comparison purposes. From Figure 9, left, it is evident that at the drop height of 1m the laminated but non reinforced parts of surfboards C and D behaved similarly as the etalon specimen *ie* showed only marginal improvement in impact resistance, namely by 5% for surfboard C and 10% for surfboard D. The same specimens ,C and D, when tested at the drop height of 2 metres showed marginal difference in impact energy by about 3% between themselves but significant improvement in impact resistance by about 25% compared to the etalon specimen. A similar qualitative trend was observed from Figure 9, right, which related to the laminated wood reinforced specimens. Differences in impact energy between surfboards were marginal with slightly better impact resistance of surfboard D against surfboard C. Comparison of impact resistance of laminated non reinforced parts of specimens C and D, Figure 9 left, and laminated wood reinforced parts of specimens C and D, Figure 9 right, showed on average of about 20% difference in impact strength , for example the improvement which was contributed to the wood reinforcement. It should be noted that both surfboards C and D were frequently used and some of the damage could be contributed to wear and delamination. This probably affected the impact strength of these structures, because the benefit of using wood stringer for specimens that were not exposed to water *eg* laminated non reinforced etalon and laminated wood reinforced specimen was much greater; about 33%.

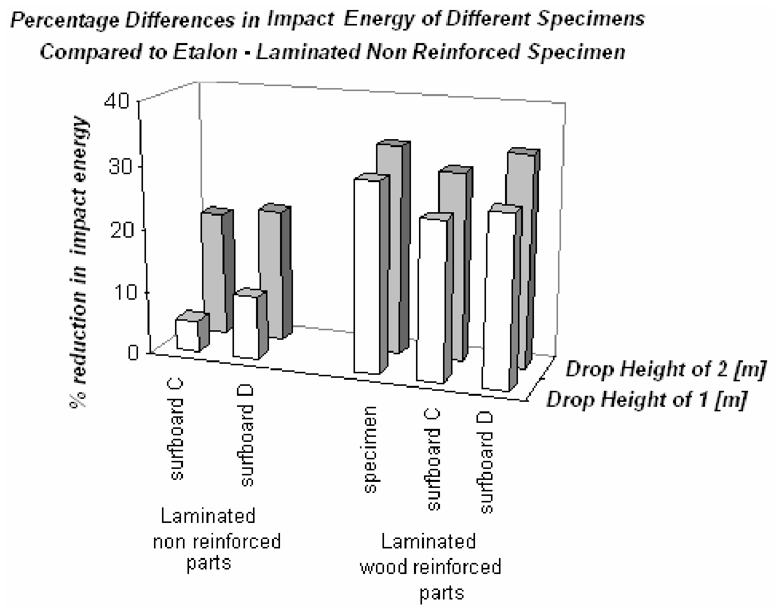


Figure 9 A histogram showing the experimental qualitative and quantitative trend in impact energy of laminated non reinforced specimens and laminated wood reinforced specimens tested with a 7kg heavy ball dropped from two different heights of 1 m and 2 m.

Numerous useful observations and conclusions, both qualitative and quantitative in nature, have been reached as a result of those strategies described in sub-Sections 3.1 to 3.3. An incorporation of the science and maths content into the classroom content appeared to have a positive response from students because it resulted in better understanding of materials and design in surf science that lead to improvements in their own boards.

4. Conclusions

Conclusions that can be drawn from this study are summarised as follows:

The authors were granted a "Teaching and Learning" grant which was used to obtain a variety of testing specimens, materials and relatively low cost measurement equipment in order to expose the students to real life testing conditions.

The students responded well and enthusiastically to the laboratory scenario because:

1. they were using real-life damaged surfboards
2. they had to create their own tests from limited resources
3. they were able to use their results and those of other students to improve the design of the surfboard they were making in another unit.

Analysis of broken surfboards showed that there are several possibilities responsible for different failure modes. Majority of boards failed by compression of the core after having one side of laminate under tension forcing laminate to yield to failure either due brittle fracture after extending the fracture strength and/or by ductile failure when extending the yield strength. These results indicated that various types of breaking mechanism that occur in surfboards during normal service conditions can be simulated by laboratory tests that were described in detail in sub-Sections 3.1 to 3.3. These straight forward experiments appear to be well suited for laboratory work needed for Surf Science Technology Program. The results showed that the strength of a core can be increased by a wooden stringer so it may be interesting to study effects of several stringers on strength and stiffness of PU foams. It would be also worth to explore the effects of different resins and cloth of flexural and impact properties of sandwich panels for surfboard industry.

d) The authors will continue in their teaching approach and research work, and intend to publish the results in scientific / engineering peer reviewed journals.

REFERENCES

1. Orbelian G.: "*Essential Surfing*", 3rd Edition, Orbelian Arts, IBSN 0-9610548-2-4, San Francisco, June 1987.
2. Manning J.A., Crosky A.G. and Bandyopadhyay S.: "*Flexural and Impact Properties of Sandwich Panels Used in Surfboard Construction*", Advanced Composites 93, edited by Chandra T. and Dhingra A.K., Minerals, Metals and Materials Society 1993, pp213 to 126.
3. Wang J.Q. and Crosky A.G.: "*Strengthening of Thin Skinned Foam Cored Sandwich Panels*", The Institute of Metals and materials Australasia Ltd, (The Materials Society of the IE Aust), Materials Research 96, Conference Proceedings Volume1, Brisbane, Australia, Wednesday 10th July, 1996, pp. 132 to 135.
4. Haines T., Audy J. & K. and Killen P.: "*Incorporation of Novel Ideas into 'Surf Equipment, Design, Materials and Construction' Course*", Conference on "*New Challenges for Sustainability and Growth in Higher Education*", Khon Kaen, Thailand, November 2004.
5. Audy J. & K. and Hatton E.: "*Exploring New Tools for Open Learning in Qualitative Education and Research Associated with Surf Science and Technology*", The 5th Qualitative Research Conference, Bournemouth, UK, September 2004.
6. ASTM D 6272-02, Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending.
7. Weissman B. D.: "*Marine Sandwich Structures Part II*", *SAMPE* Journal, **28**, (1992) 9.
8. Lingard J.R.: "*Development of a Theory for Optimising Sandwich Composites*" Advanced Composites 93, Chandra T. and Dhingra A.K., eds, (1993) 259.
9. Marshal A.C.: "Core Composite and Sandwich Structures", *International Encyclopedia of Composites*, Lee S.M., ed., VCH (1991) 488.
10. Crowe C.T., Elger D.F. and Robertson J.A.: "Engineering Fluid Mechanics" 7th Edition, J. Wiley and Sons Inc., ISBN 0-471-38482-8, USA, 2001, p. 10.

Acknowledgement

The authors would like to thank Mr. Ron Freckelton from South West Regional College of TAFE for operating testing machinery when carrying out the flexural 3 point bend test experiments described in sub-Section 3.2.

The authors would also like to thank the ECU for providing the "Teaching and Learning" grant which allowed the purchase of testing specimens.