12th International Conference on Sandwich Structures (ICSS-12) Lausanne - Switzerland, 19–22 August 2018
DOI: 10.5075/epfl-ICSS12-2018-267-269

DESIGNING AND BUILDING FOR IMPACT: QUANTITATIVE DYNAMIC SHEAR STRENGTH OF SANDWICH CORE MATERIAL

Mark Battley[1], Thomas Basset[2], Tom Allen[1], John Weber[1] and Raphael Gerard[2]
[1]University of Auckland, New Zealand. m.battley@auckland.ac.nz, tom.allen@auckland.ac.nz, jweb106@aucklanduni.ac.nz
[2] Gurit Composite Engineering, New Zealand. thomas.basset@gurit.com, raphael.gerard@gurit.com

1. INTRODUCTION

When considering structural failure during an impact, the energy that can be absorbed by the material can be more important than its ultimate static strength. Often the dynamic energy absorption is assumed to be approximated by the strain energy accumulated during a quasi-static test before failure, which depends as much on the elongation at break as on the maximum load sustained. As a result, for core materials, the shear elongation at break has thus become considered to be as important a property as ultimate shear strength [1].

Nonetheless, it has also been found that the transient nature of impact loads can cause stress and strain rates that are high enough to affect the behaviour of the core material, including the resulting strength, particularly for polymeric foams [2]. As a result, the static energy absorption is still a qualitative indication of the likely dynamic behaviour of a core material, but cannot be taken as a quantitative measure of the dynamic property by itself. The aim of this paper is to undertake characterisation of the dynamic shear strength of cores at various loading rates, in order to build a quantitative database of material performance

2. EXPERIMENTAL METHODOLOGY

Summary

A drop weight dynamic 4pt bending test was used to characterise core materials across a range of chemistry, densities, and strain rates. The different chemistries included in this study are cross-linked polyvinyl chloride (PVC, 80, 100 and 130 kg/m^3), polyethylene terephthalate (PET, 90, 110 and 135 kg/m^3) and styrene acrylonitrile foams (SAN, 80, 100 and 130 kg/m^3), representing a range of different levels of ductility and maximum elongation. Quasi-static 4pt bending was also undertaken of the same specimen types to provide benchmark static data.

Specimens

The nominal specimen geometry was 60 x 500 x 33mm (W x L x T). The upper fiberglass beam skins were thicker in the regions where the loading bars contact the specimen to prevent minimise the likelihood of localized skin failure. Specimens were manufactured by Gurit with 12 specimens provided for each core material and density.

Dynamic Beam Testing System

The high-rate beam testing was undertaken in an IMATEK IM10 Drop Weight Impact Testing system as shown in Fig. 1. Four point load and support spans of 133 and 330mm respectively were used to test the specimens. Impacts of the SAN and PVC cored beams were performed at 3.5 m/s with an impacting mass of 34.7 kg. Impacts of the PET cored beams were performed at 2.0 m/s with an impacting mass of 14.7 kg due to the low failure energy of the PET. Rubber and steel pads were placed on top of the fiberglass pads to reduce dynamic signal noise during the impact event. A high speed camera was used to record the failure process and assist in identifying and comparing failure modes.

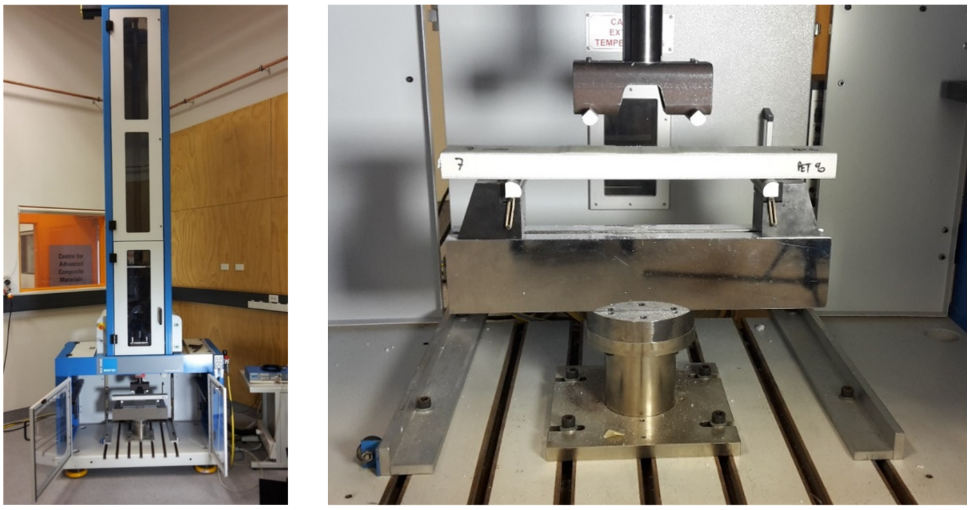

Fig. 1: Drop weight impact testing system.

3. RESULTS

Failure Modes

Under dynamic loading all of the core types failed by transverse shear as expected, however the shear failure differed between materials. The SAN foam was the most ductile, undergoing significant plastic deformation before failing in transverse shear fracture. The PVC core had some plastic deformation before also failing in transverse shear fracture. The PET cores failed as brittle transverse shear fractures. Fig. 2 compares failure modes for 100J impacts, with only plastic deformation for the SAN 100 core (top), a single crack transverse shear fracture for PVC 100 (middle) and complex multiple shear fractures for the PET (bottom).

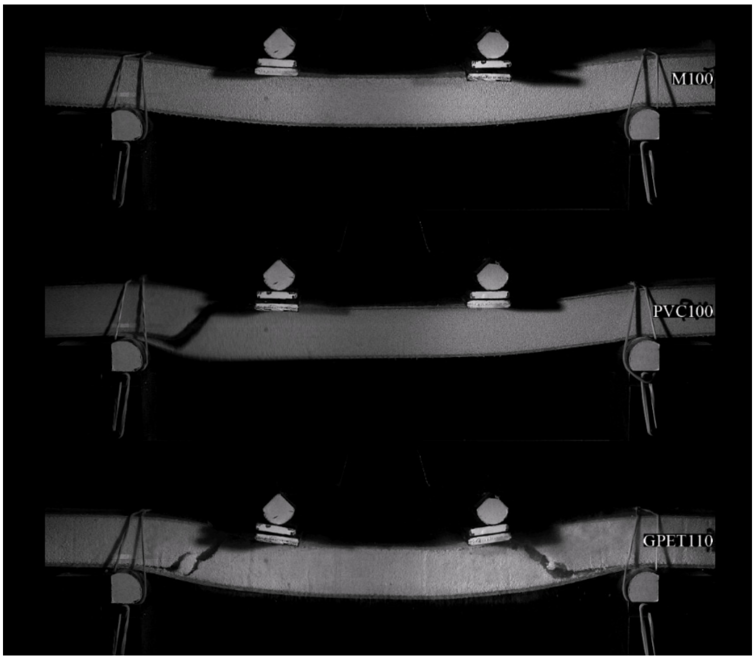

Fig. 2: Failure modes for 100J impacts.

Shear Strength and Energy to Failure

Fig. 3 presents typical load displacement curves for static and dynamic tests, taking as an example the 100 J impacts shown above for the SAN and PET samples. The high-speed camera images were used to identify the time at which fracture occurred for the energy calculations.

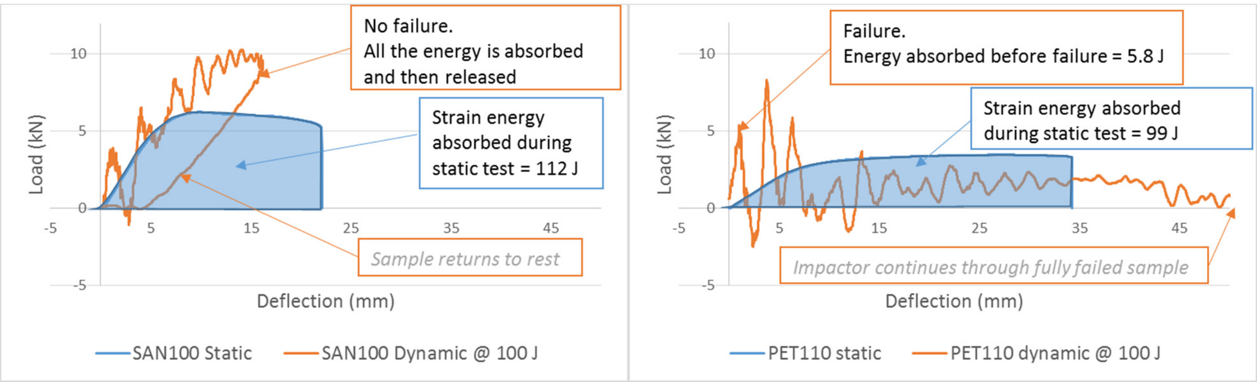

Fig. 3: Load Displacement curves for 100J impacts.

Fig. 4 compares the static and dynamic transverse shear strength and energy to failure for each of the materials. While the failure load (apparent shear strength) is higher dynamically than statically for almost all materials, the true ability of the material to sustain these loads in an impact scenario (energy absorption) varies greatly across the three material types. The SAN foam is able to absorb more energy in a dynamic impact than in a quasi-static test, whereas the PVC cannot sustain the same energy as statically, and the PET suffers a large reduction in its ability to absorb energy in a dynamic loading scenario.

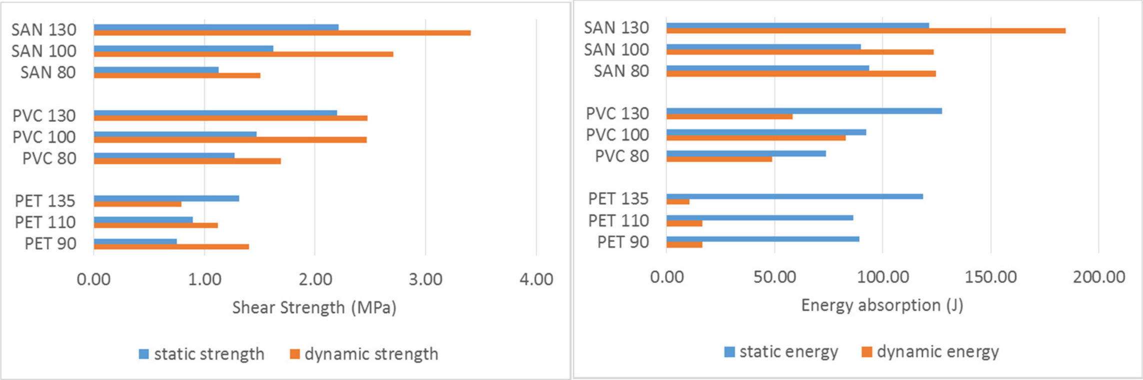

Fig. 4: Static and dynamic transverse shear strength (left) and failure energy (right).

The static shear strength increases with density for all materials, but the dynamic shear strength increases with density only for the SAN material. It plateaus at 100 kg/m3 for the PVC material, and decreases for PET, which results in PET 135 having a lower dynamic shear strength than static, actually only marginally higher than the static shear strength of PET 90.

Across material types, the static energy absorption is of a similar order of magnitude, and only follows a definite trend as a function of density for the PVC material, where it increases with increasing density. For SAN and PET the 130 (rep. 135) density is better than the 80 and 100 (respectively 90 and 110), which are close together. Overall the SAN 130, PVC 130 and PET 135 form a group of high static energy absorption materials at around 120J, SAN 100, SAN 80, PVC 100, PET 110 and PET 90 have a medium level of static energy absorption at around 90J, while PVC 80 is the material able to absorb the least energy in a static test, at 74J. The range of static energy absorption is thus 1.7 (PVC 80 at 74 J to PVC 130 at 127 J)

The dynamic energy absorption varies greatly across material types, increasing from PET to PVC to SAN, with a ratio of 17 between the material able to absorb the least energy, PET 135 at 11J, and the material able to absorb the most, SAN 130 at 185J. Within a material type, there is also no clear trend relating dynamic energy absorption ability to density: For PET, the dynamic energy absorption ability for the 135 density is lower than for the 90 and 110 densities, which have similar dynamic energy absorption ability. For PVC, 100 is higher than 130, itself higher than 80. For SAN, the dynamic energy absorption ability for the 130 density is higher than for the 80 and 100 densities, which have similar dynamic energy absorption ability.

4. CONCLUSIONS

There are significant differences in the dynamic transverse shear strength and failure energy of cores depending on the type of material. Very ductile cores such as SAN have significantly higher strengths and failure energies dynamically than statically and the dynamic strength increases with density. For moderately ductile materials such as PVC the relative dynamic strength depends on the particular density, with higher density cores not necessarily resulting in greater strengths, and the energy absorption is lower dynamic than statically. More brittle cores such as PET can have lower strengths dynamically than statically, particularly at higher densities, and can have very low energy to failure during impact loading.

The results also demonstrate that the static shear strength and strain energies to failure are not good indicators of the core material's performance during impact loading, and highlight the need to better understand the behavior of polymeric core materials during dynamic loading. Consideration also needs to be given to how best to incorporate this behaviour into material selection and design processes.

REFERENCES

[1] M. Burman et al., "Characterisation of ductile core materials", *J. Sandwich Structures and Materials*, 2010; 12-2: 237-252

[2] M. Battley, et al., "Shear Strength of Sandwich Core Materials Subjected to Loading Rates Relevant to Water Slamming", *J. Reinforced Plastic and Composites*, 2014 33-6: 506-513