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Fatigue strength of laser-welded foam-filled steel sandwich beams

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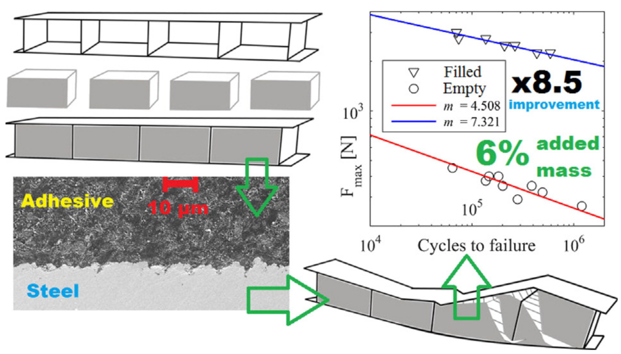
HIGHLIGHTS

- Hybrid sandwich beam is developed on the basis of reduced J-integral value at weld notch tips.
- Polymeric foam bonded to the voids of webcore beams increases weight only by 6%.
- Filled beams are tested in three-point bending for stiffness, ultimate strength and fatigue.
- Filled beams outperform empty ones by a factor of 8.5 in terms of load level at 2 million cycles.

GRAPHICAL ABSTRACT



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ABSTRACT

Laser stake-welded steel sandwich panels are widely used in engineering due to their high stiffness-to-weight ratios. The welds are thinner than the plates they join so that there are two crack-like notches on each side of a weld. As a consequence, the welded joints are susceptible to fatigue. In this study, as a remedy to the fatigue problem, low-density H80-grade Divinycell polyvinylchloride foam is bonded adhesively to the voids of stake-welded web-core sandwich beams. The foam reduces shear-induced stresses in the stake-welds. The choice of Divinycell H80 is founded on earlier J-integral-based finite element fatigue assessments of sandwich panels. Empty and the H80-filled sandwich beams are tested in three-point-bending for stiffness, ultimate strength and fatigue (load ratio $R = 0.05$). The failure modes in the weld joint region are studied using scanning electron microscopy. The experimental results show that the filling increases the stiffness of the sandwich beams by a factor of three while the weight is increased only by 6%. The ultimate strength is increased by 2.7 times. As for the fatigue behavior, the slope increases from $m = 4.508$ of empty panels to $m = 7.321$ of filled panels while the load level at 2 million cycles increases by a factor of 8.5.

1. Introduction

Demand for recyclable, light, safe and modular plate structures stimulates the study of novel structural solutions for transportation and civil engineering. Steel sandwich panels with structural cores offer an option to fulfill these requirements. Low-density cores of sandwich panels can

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Nomenclature

C	material constant used in S-N curve
E	Young's modulus
F	force
ΔJ	J-integral range
m	slope of fatigue resistance curve
N_f	number of cycles to failure
R	load ratio
ν	Poisson ratio
SED	Strain Energy Density
SEM	scanning electron microscopy

be constructed from different types of bended plate profiles, e.g. corrugations, X- and hat-profiles [1–9], or from manufactured sections such as square tubes, C- [10–11] and Z- [12–13] profiles etc.; see Fig. 1. The joining of these panels can be done by bolting or riveting [4], adhesive bonding [2,7] or by spot- [3] or laser-stake welding [16].

Web-core (or I-core) sandwich panels have the simplest core topology [14–24]. These panels have high stiffness-to-weight and stiffness-to-strength ratios. In addition, the uni-directional, hollow cores can be used for system integration (e.g. air-conditioning, cabling); see for example Ref. [25]. The potential of web-core sandwich panels can be exploited fully only when all limit states have been accurately assessed, i.e. fatigue, buckling, ultimate and accidental limit states. Once these are known, optimization can be used to find the best structural solutions for a given application; see Refs. [25–29].

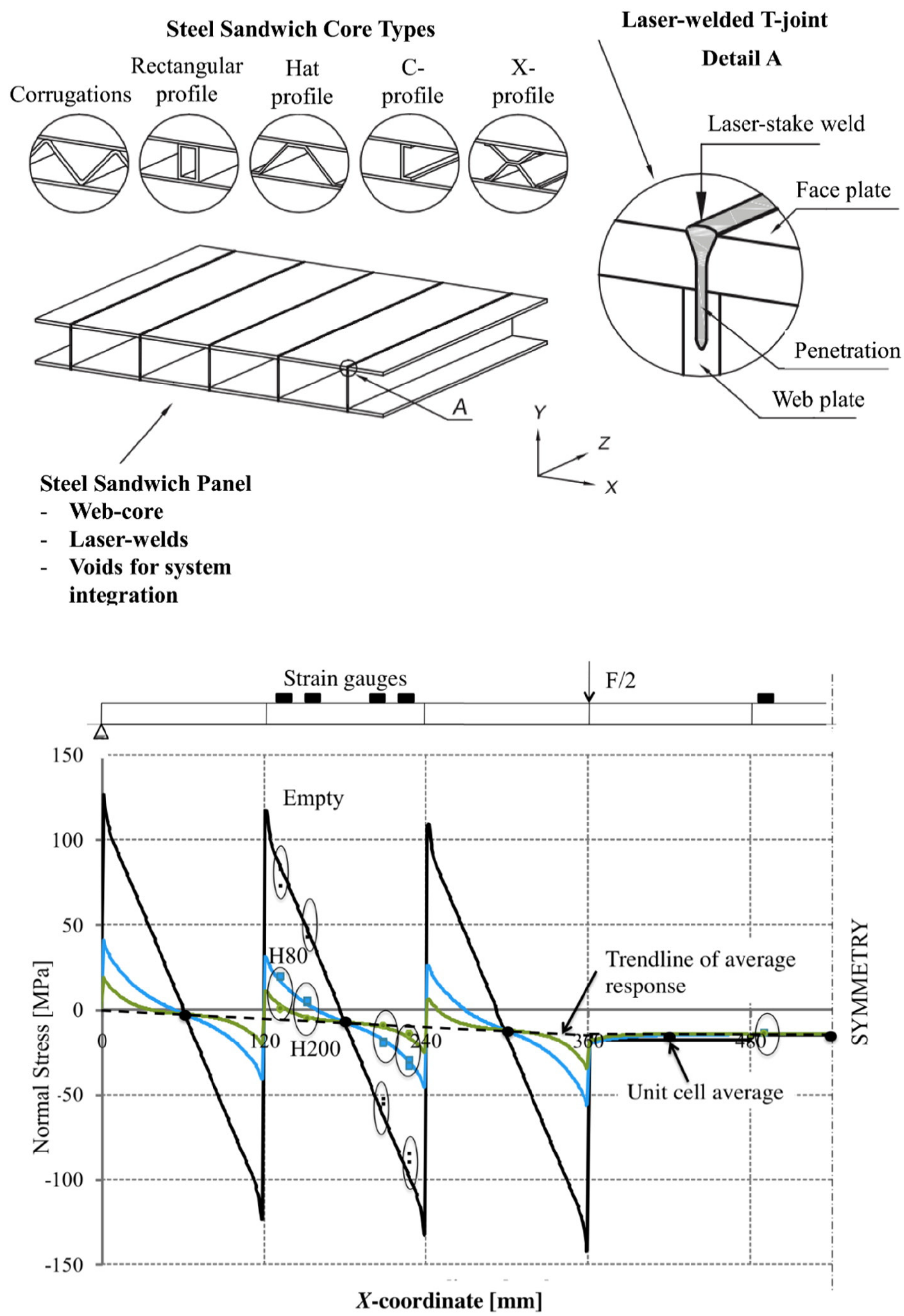

Fig. 1. Top: Laser-welded steel sandwich panels, picture adapted from [30]. Bottom: reduction of shear-induced local stresses due to filling material (Divinycell grades H80 and H200, [31]).