ADVANCED COMPOSITE STRUCTURES FOR ENHANCED THERMAL MANAGEMENT AND MECHANICAL PERFORMANCE

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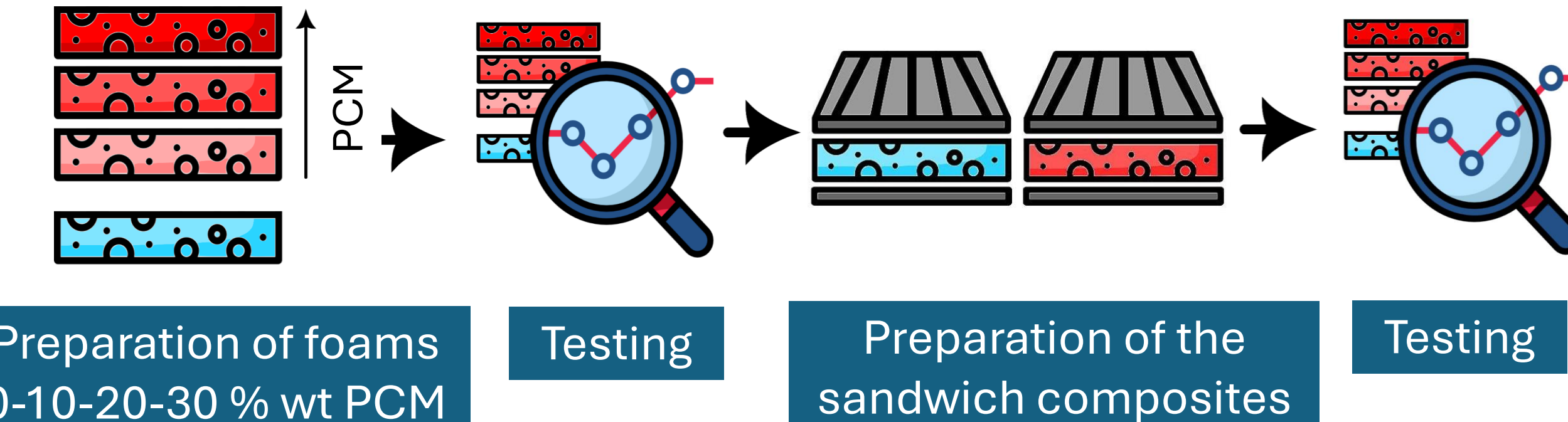
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Introduction

Compared to traditional polyurethane foam systems, **sandwich panels** with an epoxy foam core offer superior thermal and mechanical performance. **Epoxy foams** provide enhanced thermal stability, mechanical strength, and chemical resistance. They can also be combined with **phase change materials (PCMs)**, which store and release heat during phase transitions. The resulting sandwich structures are **suitable for military, aerospace, and energy-efficient applications**. Therefore, in this work an **epoxy foam–PCM core was combined with carbon fiber skins** to create high-performance sandwich composites, which were characterized for their morphology, thermal properties and mechanical behaviour.
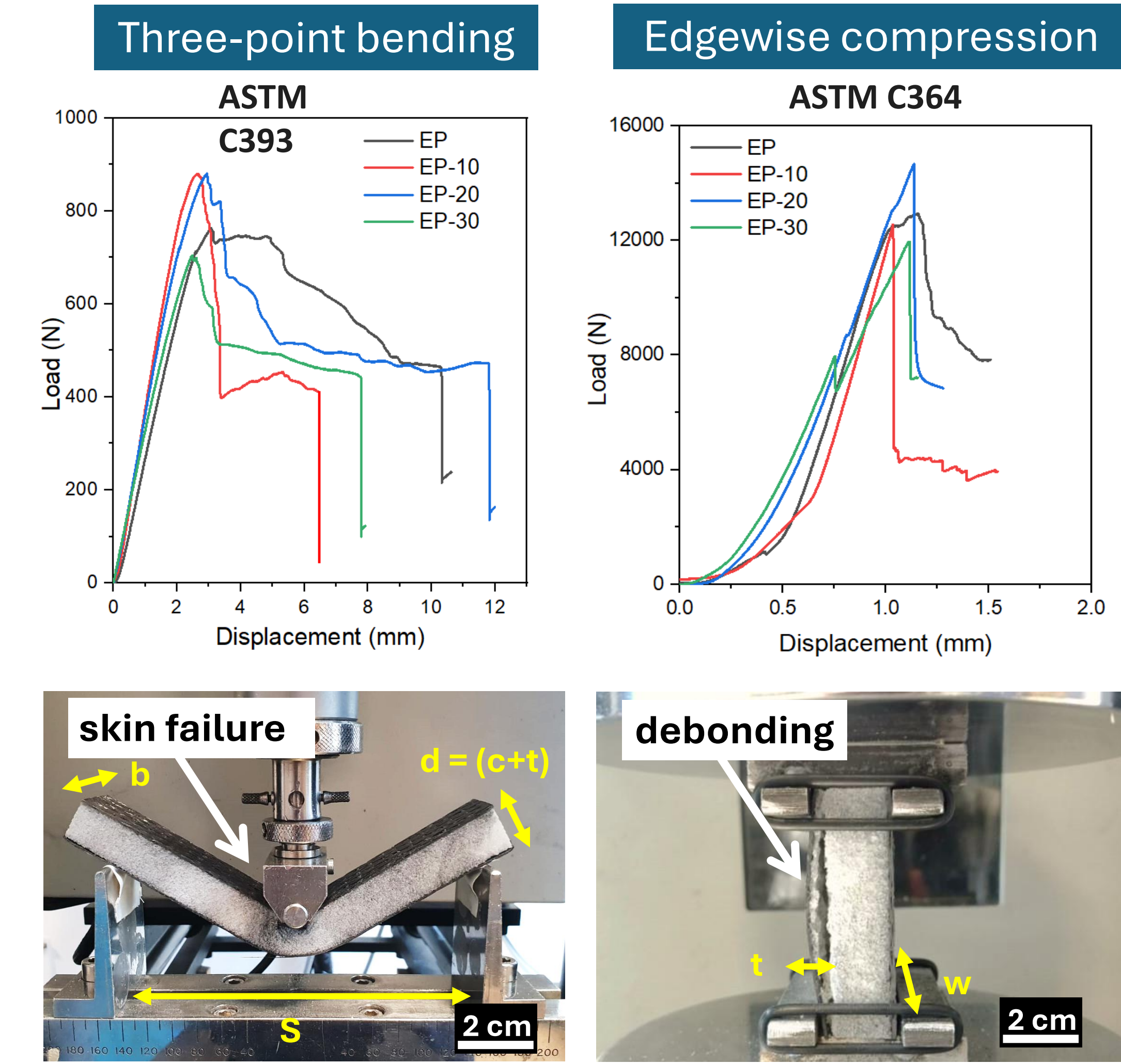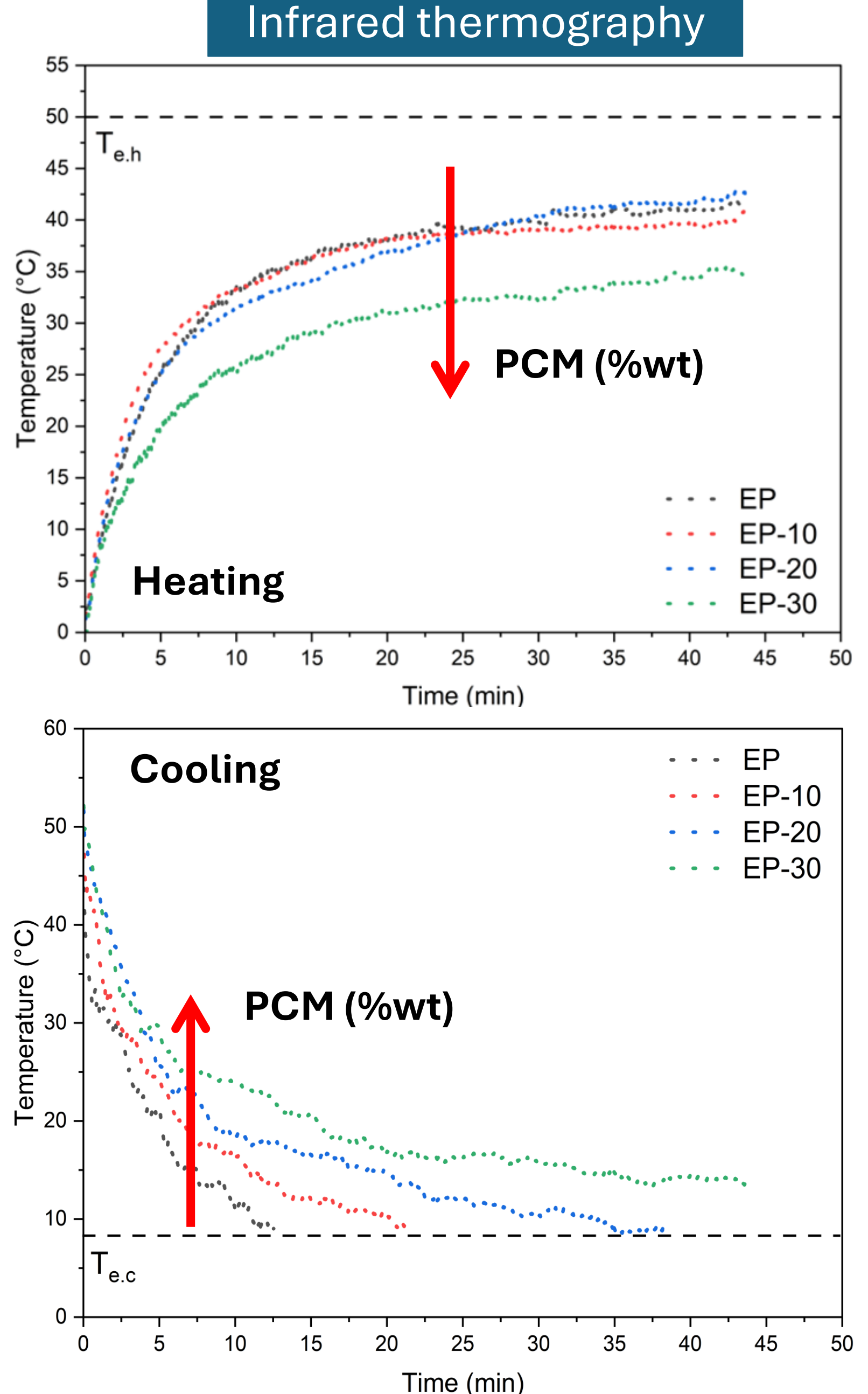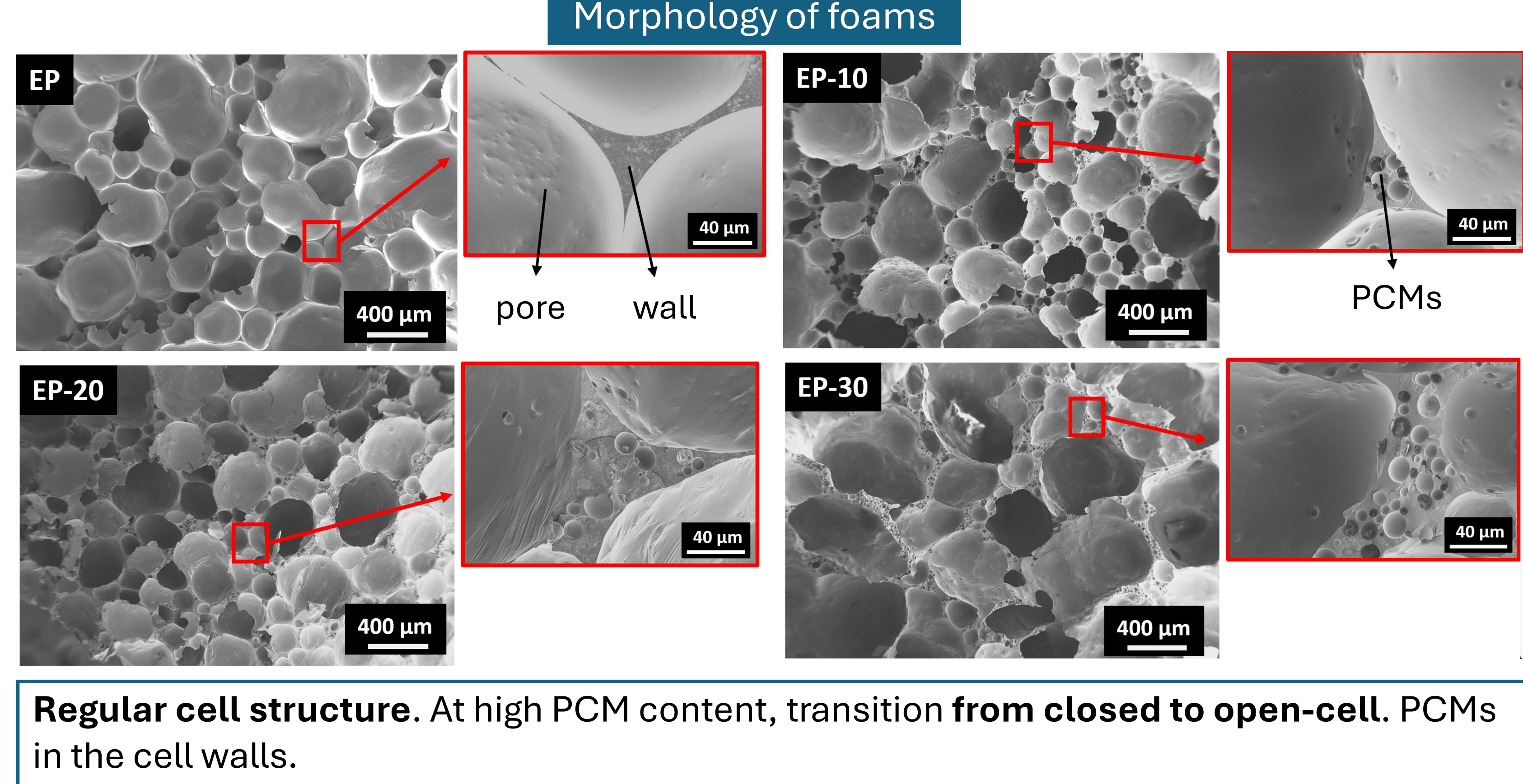
Materials

Epoxy foam	PCMs	Carbon/epoxy lamine
Elan-tech® **epoxy foam** PB170 + DM02 Elantas Europe Srl (Italy)	MPCM 32D® microencapsulated **phase change mat.** Microtek Laboratories Inc. (USA)	**Unidirectional CF** GG200P Angeloni Srl (Italy) Elan-tech® **epoxy resin** EC157 + W342 Elantas Europe Srl (Italy)

Sample preparation

Preparation of foams 0-10-20-30 % wt PCM → Testing → Preparation of the sandwich composites → Testing

Results

Morphology of foams

pore   wall   PCMs

Regular cell structure. At high PCM content, transition **from closed to open-cell**. PCMs in the cell walls.

Three-point bending

ASTM C393

Edgewise compression

ASTM C364

Core shear ultimate strength
$$\sigma_s^{ult} = \frac{P_{max}}{(d+c)\cdot b}$$

Facing stress
$$\sigma_{fac} = \frac{S\cdot P_{max}}{2t\cdot(d+c)\cdot b}$$

Edgewise compressive strength
$$\sigma_{ec}^{ult} = \frac{P_{max}}{2t\cdot w}$$

skin failure $d = (c+t)$ debonding

	Three-point bending	
Samples	σ_s^{ult} (MPa)	σ_{fac} (MPa)
EP	1.6 ± 0.1	81.4 ± 3.3
EP-10	1.9 ± 0.1	94.3 ± 5.2
EP-20	2.2 ± 0.1	109.0 ± 3.2
EP-30	1.8 ± 0.2	92.1 ± 9.6

	Edgewise compression
Samples	σ_{ec}^{ult} (MPa)
EP	77.2 ± 12.3
EP-10	66.3 ± 11.9
EP-20	88.4 ± 7.7
EP-30	69.1 ± 14.1

Infrared thermography

Heating

Cooling

Increasing PCM content **prolongs the time required to reach temperature equilibrium** during both heating and cooling.

Sandwich samples showed excellent **structural integrity** and **interfacial adhesion** skin/core. In particular, **sandwich EP-20** showed the best results from both three-point bending and edgewise compression tests.

Conclusions

- Successfully developed and characterized novel **sandwich composites** that **synergistically integrate structural load-bearing capability with thermal management properties**.
- **Skin/core adhesion** remained excellent also with PCMs.
- Sandwich composites with PCMs had **comparable or improved mechanical properties** to control sample.
- Applications where lightweight yet robust thermoregulating composites are needed, like **refrigerated transportation, aerospace and automotive**.

Acknowledgements

Bibliography

Patekar V, et al. State of the art review on mechanical properties of sandwich composite structures. *Polymer Composites,* **2022**, 43, p. 5820.