

Support-Removal Effects on Fine Features and Internal Geometries: Access, Load Transfer, Surface Damage and Verification

A qualification framework for post-build support release

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Abstract

Supports enable vat-photopolymerised parts to survive printing, but their removal is a separate manufacturing operation. Cutting, peeling, twisting, dissolving or thermal release transfers load into a partially or fully cured network. Fine walls can bend or crack, contact scars can erase functional detail, and inaccessible internal supports can remain undetected. A part that meets dimensional requirements before support removal may fail after it.

This review defines qualification of support removal for fine features and internal geometries. It links support design to access, removal sequence, local load path, material state, surface damage and verification. It requires representative destructive trials, inspection sensitivity and explicit acceptance rules. No universal tip diameter, support density, removal time or post-cure sequence is supported.

Keywords: vat photopolymerisation; support removal; fine features; internal geometry; surface damage; access; verification

1. Significance and scope

Support removal is frequently treated as manual finishing, yet it determines whether printed geometry survives and whether hidden material remains. Recent multi-material VPP research explicitly targets supports that dissolve without damaging intricate structures [1,2], confirming that removability is an engineering constraint rather than an afterthought.

ER-250 owns the effects and verification of support removal on fine external and internal geometry.

1.1 Corpus boundary

ER-010 retains general dimensional metrology; ER-035 cure interpretation; ER-033 washing- and drying-induced extraction; WP-06 post-processing and cleaning chemistry for VPP; ER-088 surface-roughness metrology; ER-181 post-cure process engineering; ER-249 projection seams; and ER-359 orientation optimisation. ER-250 owns only the post-build removal operation: access to supports, load transfer during detachment, removal-induced damage, retained-support verification and the qualification of those outcomes. It consumes washing, cleaning, post-cure, roughness and orientation states from their incumbents without redefining them. ER-249 is a roadmap neighbour and provides no authority here.

2. Define the support system

Record support material, topology, tip geometry, contact area, density, orientation and connection to the part. Distinguish breakaway, cut, soluble, meltable and sacrificial supports. Jiang, Xu and Stringer provide general support-structure design context [3], but that review does not by itself qualify post-build removal damage or hidden-volume clearance. Each support class creates a different load and residue pathway.

3. Define removal state

State whether removal occurs before washing, after washing, before post-cure, after partial cure or after full cure. Modulus, toughness, swelling and adhesion change across these states. The easiest removal condition may not give the lowest damage.

4. Establish access

Map tool approach, line of sight, fluid access and extraction path for every support. Internal supports require an exit path after detachment. A reachable contact is not removable if the released fragment cannot leave the cavity.

5. Analyse load transfer

Cutting and fracture loads travel through the support into local walls, edges and junctions. Evaluate bending moment, peel direction and constraint. Remove supports in a defined sequence that avoids concentrating load on the weakest remaining feature.

6. Measure removal force

Where damage risk is significant, measure force or torque with representative coupons. Record rate, tool and operator method. A subjective description such as easy removal is not transferable evidence.

7. Protect fine features

Challenge minimum wall, pin, lattice strut, edge and hole dimensions. Place supports at representative distances and orientations. Inspect elastic recovery, permanent bend, crack, chip and feature loss after removal.

8. Control contact scars

Support tips can leave pits, raised remnants or torn surfaces. Measure scar depth, height, area and roughness where function requires it. Cosmetic acceptance cannot replace sealing, optical, fatigue or fit requirements.

9. Internal geometries

For channels, lattices and cavities, qualify access and removal using transparent witnesses, sectioning, computed tomography or another validated method. Weight loss or fluid passage alone may miss retained fragments.

10. Soluble and sacrificial supports

Tang and colleagues demonstrated rapidly dissolvable recyclable VPP supports for complex structures [1]. Diaco and colleagues reported dual-wavelength VPP with dissolvable supports [2]. These approaches can reduce mechanical loading but introduce solvent access, swelling, compatibility, residue and endpoint questions.

11. Washing interaction

Support networks can shield uncured resin or trap wash liquid. Compare removal-before-wash and wash-before-removal where permitted. Confirm that the chosen sequence does not seal contamination inside channels.

12. Post-cure interaction

Post-curing can raise stiffness and reduce ductility, changing breakaway behaviour. Conversely, early removal can deform a weak green part. Determine the removal window experimentally for each material and feature class.

13. Tool control

Specify cutters, blades, fixtures, ultrasonic methods, jets or automated tools. Control sharpness, alignment, travel and guarding. Tool qualification includes the inaccessible and worst-angle locations, not only open surfaces.

14. Operator and automation effects

Manual work introduces sequence and force variability; automation introduces positioning and compliance errors. Measure repeatability across operators or cycles. Training instructions are part of the controlled process.

15. Verification sensitivity

Define the smallest retained support, scar, crack or deformation that must be detected. Demonstrate probability of detection or bounded sensitivity with seeded defects. Visual inspection alone is unsuitable for hidden geometries unless validated.

16. Functional verification

Use leak, flow, optical, fit, electrical, mechanical or biological-cleanliness tests where relevant. Dimensional conformance does not prove that removal preserved function.

17. Destructive validation and sampling

Section representative parts during process qualification and after material or design changes. Routine non-destructive inspection must be correlated with destructive truth data. Define sampling and escalation rules.

18. Change control

Requalify after changes to resin, support material, tip, topology, orientation, cure state, washing, solvent, tool, operator method, internal access, minimum feature or inspection system.

19. Non-compensatory qualification matrix

Gate	Required evidence	Shortcut prevented
Access	Contact and fragment extraction paths	Assuming visible means removable
Load	Force and weak-feature survival	Using support density as safety proof
Surface	Scar and residue measurements	Cosmetic inspection alone
Internal	Validated hidden-volume inspection	Inferring clearance from flow only
Chemistry	Compatibility and endpoint for dissolution	Treating disappearance as cleanliness
Function	Application-relevant endpoint	Accepting dimensions without performance

Failure of any gate rejects the removal process for that geometry.

20. Minimum reporting set

Report part and support materials; resin lot; support topology, tip and contact geometry; part orientation; minimum features; removal cure state; wash and post-cure sequence; tools and fixtures; access and extraction maps; removal order; measured force or proxy; solvent, temperature and time for dissolution; scar and deformation metrology; internal inspection method and sensitivity; seeded-defect study; functional results; operator or automation repeatability; acceptance limits; raw-data hashes; and change triggers.

21. Knowledge boundary and limitations

References [1] and [2] were examined at publisher-abstract and full-text depth, respectively. They demonstrate dissolvable-support strategies but do not validate every resin, solvent or internal geometry. Reference [3] was examined at full-text depth and supplies general support-design context. No cited source establishes universal removal force, contact size, solvent time or inspection sensitivity.

22. Conclusions

Support removal is a controlled load, access and verification problem. Qualification must show that contacts can be reached, fragments can exit, fine features survive, scars remain acceptable and hidden volumes are clear. The qualified output is a geometry-specific removal and inspection process, not a generic instruction to remove supports carefully.

References

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