HB-AR-ACC-01, Automated Contour Crafting of Sintered Basalt Load-Bearing Walls

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February 2026

Abstract

This technical report details the structural derivation and robotic implementation of the **HB-AR-ACC-01** protocol. The study focuses on the additive manufacturing of load-bearing structures using in-situ sintered basalt (ISB). We analyze the thermal gradients required for localized melting of regolith and the resulting compressive strength of double-curved contour-crafted shells. This archetype is designed for atmospheric pressures $< 10^{-9}$ Torr, providing a radiation-shielded habitat solution for extreme planetary architectures.

1 Introduction

Automated Contour Crafting (ACC) represents the pinnacle of autonomous off-world construction. Traditional masonry is unfeasible due to logistics; therefore, the **HB-AR-ACC-01** protocol utilizes a high-energy laser-sintering head (HEL-S) to fuse basaltic regolith layer-by-layer. Unlike terrestrial 3D printing, the absence of an atmosphere allows for rapid cooling and precise control over the thermal crystallization of the basalt matrix.

2 Material Properties and Sintering Kinetics

The raw material consists of pulverized basaltic regolith with a high concentration of SiO_2 and FeO. The sintering process is governed by the localized heat flux Q delivered by the HEL-S unit.

2.1 Thermal Diffusion Equation

The temperature field $T(r, z, t)$ during the deposition of a single contour layer is defined as:

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + A(r, z, t) \tag{1}$$

Where A is the laser heat source term. In the vacuum of the *HB_02-07* sector, heat loss via convection is zero, leaving radiation as the primary cooling mechanism:

$$q_{rad} = \epsilon \sigma (T^4 - T_{space}^4) \tag{2}$$

3 Structural Mechanics of Sintered Shells

The load-bearing capacity of the ACC walls depends on the "inter-layer bond" efficiency. We model the wall as a non-homogeneous thin shell subject to gravitational and internal pressure loads.

3.1 The Cauchy Stress Tensor in Sintered Basalt

The internal stress distribution σ_{ij} within the sintered basalt wall must satisfy the equilibrium condition:

$$\nabla \cdot \sigma + \mathbf{f}_{ext} = 0 \tag{3}$$

For a sintered basalt matrix, we observe a brittle-to-ductile transition at $T > 1100K$. The effective Young's Modulus E_{eff} is a function of the sintering degree α:

$$E_{eff}(\alpha) = E_{max} \cdot \left(\frac{\alpha - \alpha_c}{1 - \alpha_c} \right)^p \tag{4}$$

Where α_c is the percolation threshold for load-bearing contact.

4 Robotic Path Optimization (ACC Protocol)

The **HB-AR-ACC-01** algorithm optimizes the toolpath to minimize residual thermal stresses. The contour path is defined by a parametric spline $\mathbf{r}(s)$:

$$\mathbf{r}(s) = \sum_{i=0}^{n} B_i(s) \mathbf{P}_i \tag{5}$$

The printing speed v_p must be synchronized with the cooling rate to prevent catastrophic fracturing of the sintered layer.

5 Numerical Results: Compressive Strength

Simulations performed under Lunar-standard gravity ($1.62 m/s^2$) show that a wall thickness of $0.45m$ can support a vertical load of $1.2MN/m$ with a safety factor of 3.5.

Parameter	Value	Units
Sintering Temp	1450	K
Compresive Strength	120	MPa
Density (ρ)	2800	kg/m^3
Thermal Conductivity	1.2	W/mK

Table 1: Material properties of sintered basalt walls (HB-AR-ACC-01).

6 Conclusion

The integration of automated contour crafting with in-situ material sintering provides a scalable solution for extreme architecture. The **HB-AR-ACC-01** protocol ensures that load-bearing walls can be constructed autonomously, meeting the Level 7 clearance requirements for deep-space habitat integrity.

References

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