

INTRODUCTION

With current initiatives to return to the lunar surface, there is a necessity for autonomous and ISRU-capable technologies for lunar landing site preparation. Our current research is focused on developing a robotically deployed induction furnace system with an integrated brick molding nozzle. The proposed system will use feedstock of raw lunar regolith to produce bricks on the lunar surface. This study evaluates the effects of the heating protocol on the compressive strength of lunar regolith simulant CSM-LHT-1.

SIMULANT

CSM-LHT-1 mineral composition primarily consists of plagioclase, accompanied by smaller amounts of pyroxene and olivine [1]. Table 1 summarizes the geotechnical properties of the powdered material as assessed by Martin and Wagoner [2].

Table 1: Geotechnical Properties of CSM-LHT-1

Minimum Density [g/cm ³]	1.43
Maximum Density [g/cm ³]	1.57
Specific Gravity	2.81
Cohesion [kPa]	12
Friction Angle [°]	32

METHODS

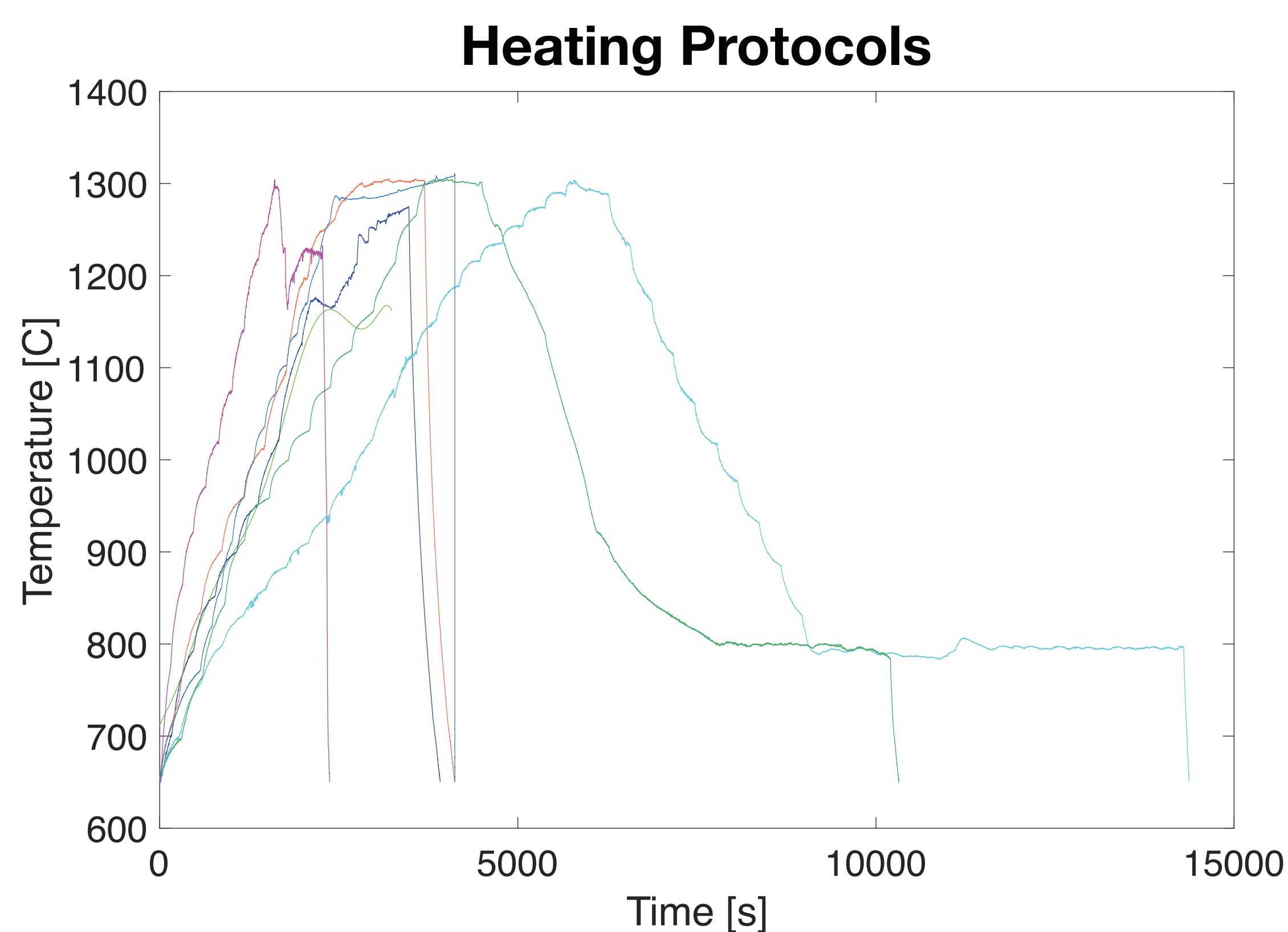


Figure 1: Heating Protocols

Melting. Tests used 75 g of CSM-LHT-1 in a graphite crucible. It was placed in an induction furnace with a coil connected to an induction heater. Heating rate varied from 8 °C/min to 33 °C/min, increasing current by 25-50 A every 5 minutes. After reaching the desired temperature, the sample was quenched or cooled at 10 °C/min and annealed. Figure 1 shows heating curves.

Density Measurement. Solidified cylindrical bricks, 35 mm diameter and 35 mm height, were weighed again to determine the loss of volatiles. At The Heat and Mass Transfer & Experimental Rheology (HAMSTER) lab at The University of Texas at San Antonio (UTSA), an Anton Paar Ultrapyc 3000 gas pycnometer with helium gas determined true volume for bulk density calculation.

Uniaxial Compression Test. Ultimate compressive strength was tested at UTSA's Large-Scale Testing Lab using a 100 kN Universal Testing Machine (MTS). Samples were compressed at 0.014 mm/s until failure, adhering to ASTM C39/C39M.

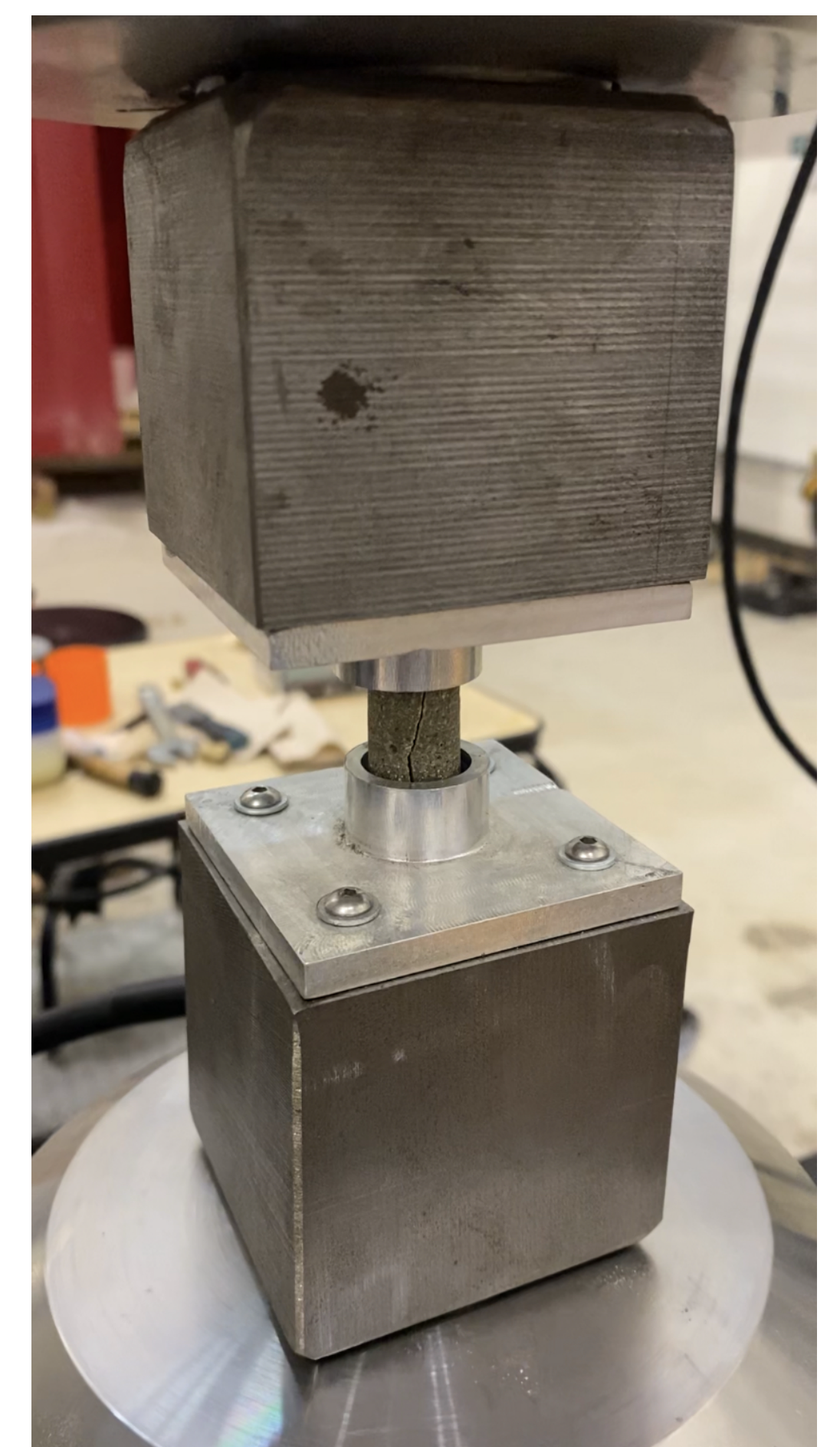


Figure 2: Compression Test

Prior to the test, cores of roughly a 2:1 ratio were drilled from bricks. Modified ASTM C1231/C1231M protocol was used to design retaining rings with neoprene pads, ensuring alignment and compensating for surface porosity (Figure 2).

RESULTS

The melting process, which occurred at temperatures ranging from 1150°C to 1310°C, resulted in closed porosity levels observed in the range of 0.68% to 2.55%. The bulk density of the solidified cylindrical bricks fell within a short range of 2.7636 g/cm³ to 2.8168 g/cm³, with a coefficient of variation less than 1%. The ultimate compressive strength varied from 18 MPa to 98 MPa, with a mean value of 43 MPa (Figure 3).

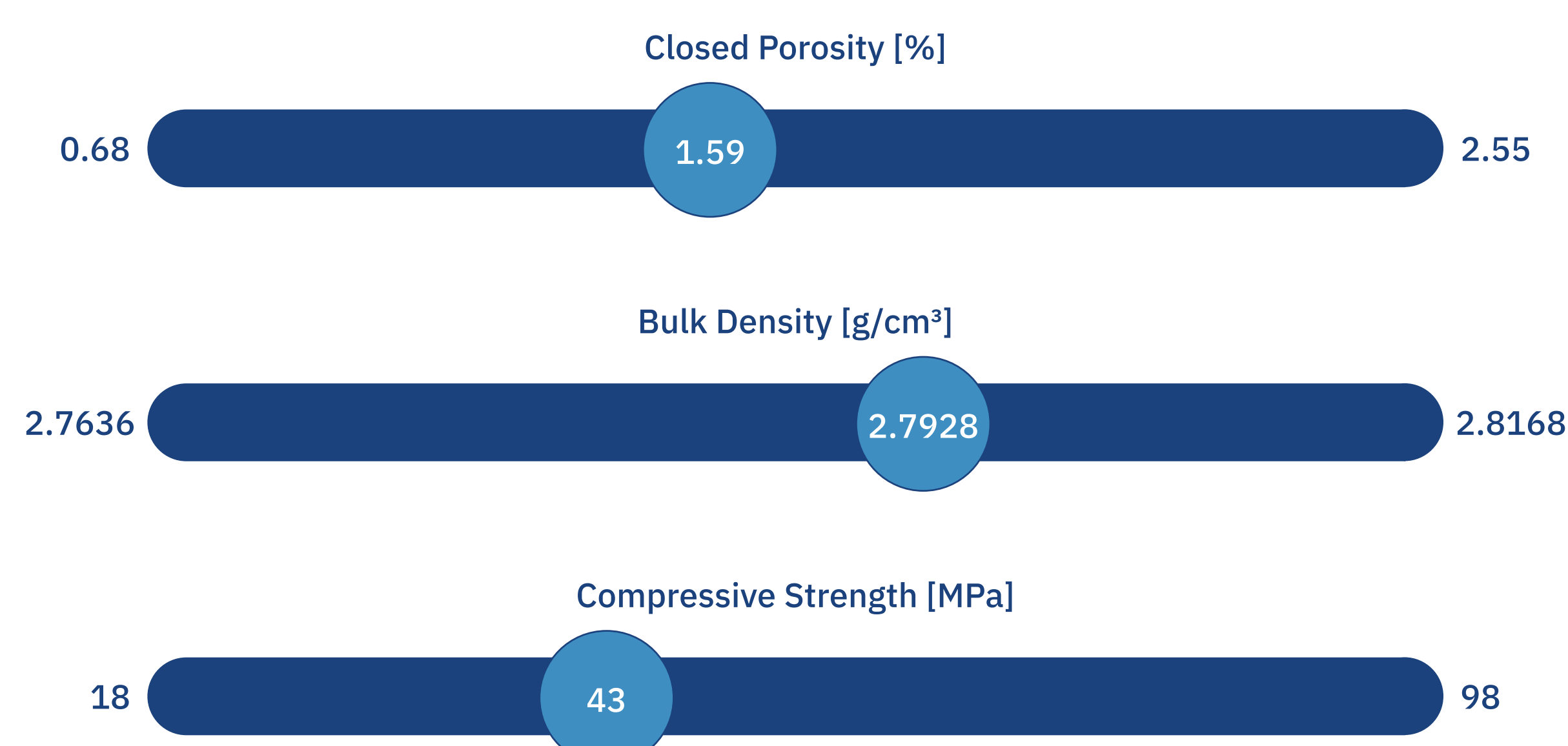


Figure 3: Summary of Results

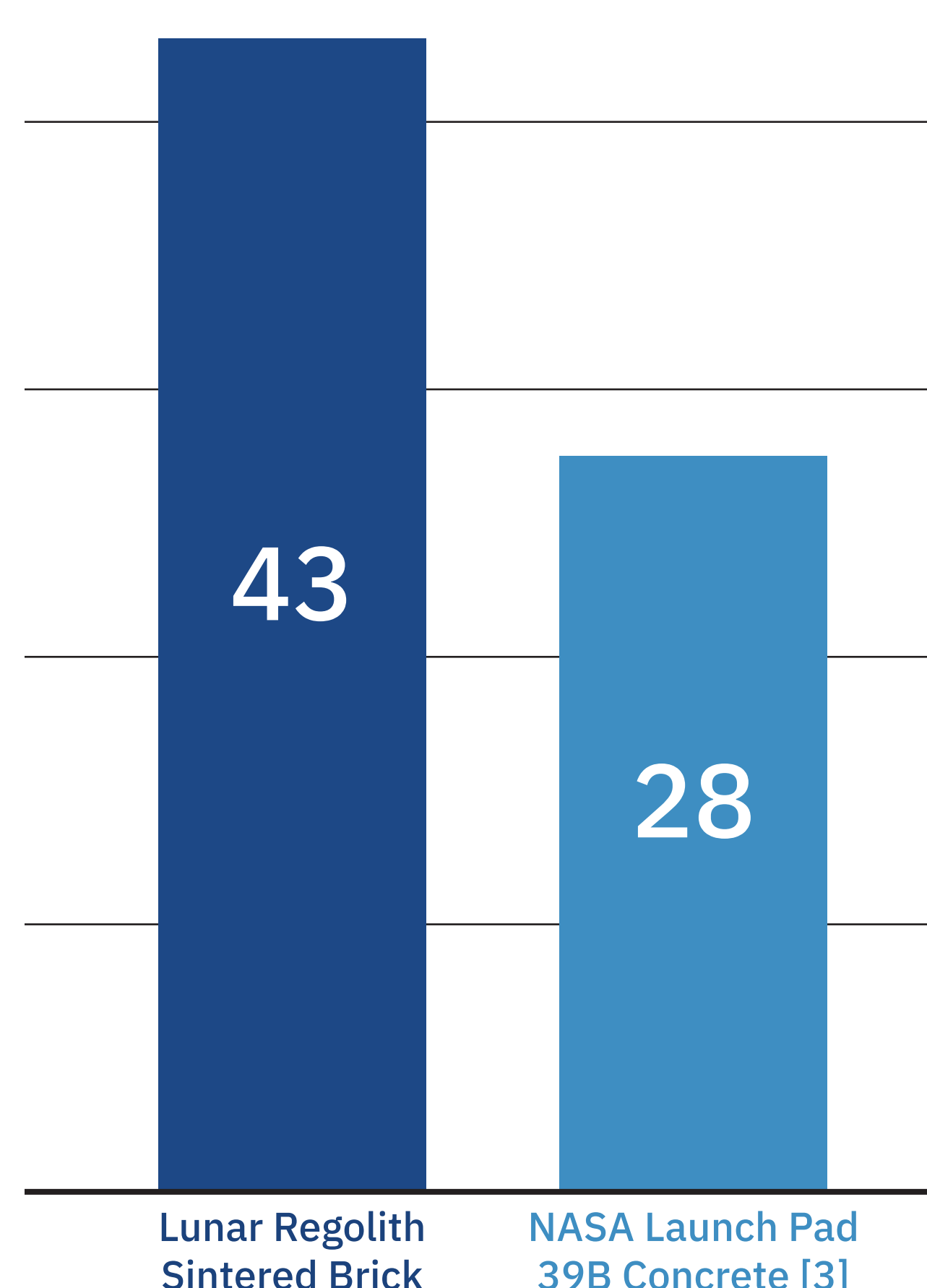


Figure 4: Comparison of Compressive Strengths [MPa]

Figure 4 compares the compressive strengths [MPa] of the lunar regolith sintered brick and the concrete used at NASA Launch Pad 39B, as reported by Weyers et al. [3]. The sintered brick is 15 MPa stronger than the concrete which establishes a 54% improvement in strength. Experimental observations of vertical cracks in the compressed cores revealed the common failure mode to be longitudinal splitting (Figure 2).

CONCLUSION

Bricks strong enough to support the launch and landing of spacecraft are produced even with relatively low temperatures.

Strength improvement of

54%

relative to NASA launch pad concrete.

The predicted failure mode involves longitudinal splitting, directing future research toward optimizing the shape of the bricks.

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3. San Antonio Belting & Pulley

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- [3] Weyers, R. E., Sagüés, A. A., & Zemajts, J. Z. (2015). Condition assessment of launch pad 39B. Concrete International, 45-53.