

1 **A Fractal Approach to Size-Dependent Rock Strength in Environmental**
2 **Geomechanics**

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7 **Abstract.** Understanding the mechanical reliability of rock mate-
8 rials is essential for environmentally sensitive engineering appli-
9 cations, including slope stabilization, shallow tunneling, and foun-
10 dation design. Variations in specimen size—particularly the
11 length-to-diameter (L/D) ratio—can significantly affect the con-
12 sistency of mechanical parameters used in rock characterization.
13 This study examines the effect of L/D ratio on the reliability of
14 uniaxial compressive strength (UCS), elastic modulus (E), and
15 Poisson’s ratio (ν) in marble core specimens. To provide a more
16 comprehensive assessment, a novel dimensionless indicator, the
17 Fractal-Integrated Strength Index (FISI), is introduced. The FISI
18 integrates the mean and variability of UCS and E with the fractal
19 dimension (Df) of axial stress–strain curves, determined through
20 the box-counting method in fractal analysis. Experimental results
21 reveal that specimens with an L/D ratio of approximately 2.5 ex-
22 hibit the most stable and consistent mechanical behavior, accom-
23 panied by lower variability in Df values. In contrast, Poisson’s ra-
24 tio demonstrates persistent inconsistency regardless of L/D, indi-
25 cating that it is less sensitive to specimen size optimization. By
26 integrating strength, stiffness, and fractal complexity within a sin-
27 gle metric, the FISI provides a robust metric of evaluating rock
28 behavior. This integrated approach enhances the reliability of ge-
29 omechanical assessments, particularly in projects where both en-
30 vironmental considerations and structural safety are critical. The
31 findings highlight the value of linking conventional mechanical
32 testing with fractal analysis to better capture the complexity of
33 rock deformation. Integrating both core size effects and fractal-
34 based evaluation into testing protocols can improve the accuracy
35 and reliability of rock strength characterization, ultimately sup-
36 porting safer and more sustainable engineering applications in en-
37 vironmentally sensitive projects.

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39 **Keywords:** Fractal-Integrated Strength Index (FISI), Rock Mechanical
40 Behavior, Size-Dependent Effects, Environmental Geomechanics.