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Development of an Innovative Shape Factor for Dimension Stone Blocks in Stone Quarries: A Geotechnical Approach

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Abstract
Dimension stones have played a vital role in human civilization for over 12,000 years, serving both functional and aesthetic purposes. However, discontinuities within rock masses significantly reduce the efficiency of extraction and processing, resulting in irregular block shapes and increased waste. This study introduces a novel shape factor formula designed to quantitatively assess the quality of stone blocks by comparing them to an ideal rectangular cuboid. The proposed formula incorporates block flaws, including corner and edge discontinuities, and utilizes geometric parameters such as diameters and weight ratios. Validation was performed using ten granite samples from the Black Granite Ghoi quarry in Nehbandan, Iran. The calculated shape factors ranged from 0.18 to 0.97, demonstrating a strong correlation between block completeness and quality. Compared to previous methods, such as the volumetric ratio and blockiness index, the new formula reduces classification errors and avoids unrealistic outputs (e.g., values exceeding 1). This innovative approach offers a scalable and precise tool for evaluating stone blocks across diverse geological settings. Its integration into quarry operations can enhance resource optimization, reduce waste, and support global standardization in dimension stone classification.

Keywords Quarrying direction · Block geometry · Block shape factor · Rock classification · Dimension stone

1 Introduction

In the construction sectors of the Middle East and Mediterranean regions, natural stones are considered essential materials due to their exceptional durability, aesthetic qualities, and cost-effectiveness compared to other construction alternatives. Furthermore, the diverse geological origins of these stones result in a wide range of mechanical properties, enhancing their versatility and suitability for various structural applications [1].

Natural stone remains a fundamental architectural material owing to its durability, strength, and aesthetic appeal, and continues to be widely utilized in modern designs. Dimension stones, including granite, limestone, marble, sandstone, and slate, are extracted and processed into specific sizes for construction purposes.

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In recent years, increasing global demand has driven significant advancements in extraction and processing technologies, substantially improving the stone industry (Fig. 1). This upward trend is expected to persist, fostering industrial innovations that enhance efficiency and sustainability [2, 3].

As with any mining activity, determining the profitability of a deposit is crucial. Comprehensive studies of the rock mass and evaluations of geological factors are essential steps to assess whether a dimension stone deposit can be exploited profitably [4, 5]. Unlike other extraction methods, where profitability is typically assessed by comparing the volume of recovered material to the total volume extracted, the success of dimension stone extraction depends on the ratio of commercial-grade blocks obtained to the total extracted volume [6].

Discontinuities within dimension stones present significant challenges, reducing the efficiency of both extraction and processing (Fig. 2) [7]. Generally, more uniform blocks with minimal discontinuities or structural defects are more economical to extract and process.

A compelling example comes from the Melika marble quarry in Kerman, Iran, where numerical modeling using 3DEC software demonstrated that reorienting the extraction

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