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Appraisal of Bekuma Marble for Cement and Dimension Block Production

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Abstract: *The suitability of marble deposits for industrial applications such as cement manufacturing and dimension block production is largely dependent on their mineralogical and chemical characteristics. Two formations of Bekuma marble (Formation I and Formation II) were evaluated for their chemical, physical, and mechanical properties.For Formation I, uniaxial compressive strength, porosity, water absorption, and slake durability were 172 MPa, 0.502%, 88.7%, and 89.3%, respectively. Its X-Ray Fluorescence (XRF) analysis revealed dominant oxides of CaO = 39.84%, MgO = 2,28%, and SiO_2 = 19.08%, indicating a high-purity calcitic marble with limited dolomitic influence and minimal siliceous impurities. These characteristics make Formation I suitable for both cement and dimension block production.Formation II, however, recorded a uniaxial compressive strength of 136 MPa, porosity of 0.868%, water absorption of 36.32%, and slake durability of 52.1. Its X-Ray Fluorescence (XRF) analysis revealed dominant oxides of CaO = 67.44%, MgO = 10.57%, and SiO_2 = 0.64%. Its higher MgO content and intense fracturing render it unsuitable for cement production, though it may have limited potential as a dimension stone due to its brittleness. Overall, Formation I marble shows a strong economic potential with dense texture, high CaO purity, and good polishability, while Formation II's chemical and structural characteristics limit its industrial applicability.*

Keywords: Bekuma marble, cement production, dimension stone, XRF analysis, mineral evaluation, physical properties

INTRODUCTION

Dimension blocks encompass a broad category of natural stone materials such as marble, limestone, sandstone, gabbro, granite, serpentine, and gneiss, widely used for both interior and exterior architectural finishes. These stones are valued not only for their durability but also for their aesthetic appeal, making them ideal for decorative applications in construction. Marble, in particular, is extensively sought after due to its polishability, workability, and visual qualities. Additionally, its high calcium carbonate content positions it as a viable raw material in cement manufacturing, where it serves as a primary source of lime a crucial component of clinker.

The extraction of dimension stone, commonly referred to as quarrying, involves the removal of large blocks or slabs from naturally occurring geological formations. The techniques adopted for quarrying depend significantly on the physical properties of the rock deposit, such as hardness, density, natural joint orientation, and degree of fracturing, as well as economic and logistical considerations. Ideally, deposits with orthogonal fracture systems are favored for block production as they allow for easier recovery of rectangular blocks. In contrast, deposits with irregular joint patterns often yield low recovery rates and require more intensive cutting and processing. For instance, in some Finnish marble quarries, usable blocks make up as little as 5–10% of the total excavated material.

Marble is a metamorphic rock primarily composed of calcite, with a Mohs hardness of about 3. This relatively low hardness can influence its performance during cutting and polishing, as it may lead to excessive grain wear, affecting the final surface finish of the dimension blocks. Other natural defects such as color variation, textural inconsistency, and structural discontinuities can also impact the market value and usability of the blocks. As such, block recovery analysis is typically performed during exploration to assess the homogeneity, jointing, and economic feasibility of the deposit.

In parallel, marble's chemical composition, particularly its high calcium carbonate content, also makes it a strategic material for cement production. The production of Portland cement requires raw materials rich in calcium oxide, silica, alumina, and iron oxide. Marble's purity and abundance of calcite can serve as a cost-effective and locally available substitute or supplement for traditional limestone in cement clinker formation. This dual-purpose potential both as a decorative material and as an industrial mineral makes marble an attractive resource, especially for developing regions seeking to expand their construction material base and industrial output.

In the context of Nigeria, and specifically in the Akoko Edo region where the Bekuma Marble deposit is located, current industrial activity has been largely focused on the production of marble boulders and powders. The introduction of dimension block production and cement-grade marble processing could offer new economic opportunities, reduce dependency on imported materials, and contribute to the diversification of the local mining sector. Therefore, this study aims to assess the suitability of Bekuma Marble for both cement production and dimension block applications through comprehensive geological, physical, and chemical evaluations.

LITERATURE REVIEW

Overview of Marble and Its Industrial Applications

Marble is a metamorphic rock composed predominantly of calcite ($CaCO_3$), formed through the recrystallization of limestone under conditions of high pressure and temperature. Its compact crystalline structure, aesthetic appeal, and mineral purity make it a valuable resource in both decorative and industrial applications. The global marble industry is traditionally bifurcated into two major sectors: the dimension stone industry, which emphasizes aesthetic and structural properties, and the cement industry, which focuses on its chemical composition, particularly calcium carbonate content.

Marble as a Raw Material for Cement Production

In cement manufacturing, raw materials rich in calcium oxide (CaO) such as limestone and marble are essential for the production of clinker, which is then ground to produce Portland cement. The typical raw mix for clinker production includes calcareous materials (mainly $CaCO_3$), siliceous materials (SiO_2), and minor quantities of alumina and iron oxide. According to [7], marble with high $CaCO_3$ content and low impurities can serve as a suitable alternative to traditional limestone in cement production. Research by Okonkwo et al. [6] indicates that certain Nigerian marble deposits possess sufficient purity to meet cement-grade standards, particularly when blended with other corrective materials.

Dimension Blocks: Geological and Mechanical Considerations

Dimension blocks are extracted slabs or blocks of natural stone used primarily in construction and architecture for façades, flooring, walls, and decorative elements. The quality of a stone for this purpose is judged based on criteria such as color uniformity, grain texture, structural soundness, workability, and durability. The American Society for Testing and Materials (ASTM C615) outlines key performance metrics for building stones, including compressive strength, abrasion resistance, and water absorption.

According to Török and Vásárhelyi [8], one of the critical determinants of a rock's suitability for dimension stone is the presence of naturally occurring orthogonal joint systems, which enable easier extraction of rectangular blocks. Conversely, irregular or closely spaced joints can significantly reduce recovery rates. Finnish marble quarries, for example, often report commercial recovery rates as low as 5–10% due to these natural defects [4].

Common Defects and Limitations in Dimension Block Production

Several factors affect the yield and quality of dimension blocks. Color variation, textural inconsistency, and the presence of macro-structural discontinuities (such as veins, faults, and micro-fractures) reduce the exploitability of marble for decorative uses [3]. Moreover, calcitic marbles, with a Mohs hardness of about 3, are relatively soft, making them vulnerable to surface damage during cutting and polishing. These issues can affect both the aesthetic value and durability of the final product.

Despite these challenges, dimension marble is valued for its visual appeal and ease of shaping. Studies by Çelik and Sabah [2] have shown that pre-exploration testing, including block recovery analysis and fracturing studies, can help mitigate economic losses during quarrying operations.

Marble Deposits in Nigeria

Nigeria is endowed with significant marble deposits, particularly in the Middle Belt and southwestern regions. Previous studies have identified regions like Igbeti, Jakura, and Okpella as key marble-producing areas. According to Ajibade et al. [1], Nigerian marbles generally have high calcite content, making them suitable for both cement manufacturing and dimension stone applications.

Specifically, the Bekuma area in Akoko Edo LGA, Edo State, has been noted for its marble and limestone occurrences. However, industrial activity in the region has been largely confined to powder and boulder production for filler and lime use. There remains a gap in knowledge and utilization concerning its potential as a high-grade cement raw material and dimension block source.

Economic and Environmental Considerations

The expansion of marble quarrying for cement and dimension block production presents both opportunities and challenges. Economically, local processing can reduce reliance on imports and stimulate rural industrialization. However, environmental implications such as land degradation, noise, dust generation, and biodiversity loss must be managed. According to Obaje [5], sustainable mining practices and value-added processing (e.g., cutting, polishing, and cement blending) are essential for long-term viability in Nigeria's industrial minerals sector.

METHODOLOGY

Study Area and Geological Setting

The Bekuma Marble deposit is located in the Akoko Edo Local Government Area of Edo State, Southwestern Nigeria. Geologically, the area lies within the Basement Complex terrain of Nigeria, characterized by migmatites, gneisses, schists, quartzites, and intrusions of granites and pegmatites. Marble deposits in this region are associated with calc-silicate rocks formed by contact or regional metamorphism of carbonate-rich sediments. The choice of the study area was based on preliminary geological mapping, evidence of ongoing marble extraction, and accessibility for sampling and testing.

Field Investigation and Sample Collection

Representative marble samples were collected from exposed faces and abandoned sections of the Bekuma quarry. Sampling was carried out across different quarry faces to ensure the collection of geologically varied specimens that reflect changes in texture, color, jointing, and mineral composition. Approximately 100–150 kg of block samples were extracted using sledgehammers and chisels for both chemical and mechanical testing.

GPS coordinates of each sampling point were recorded, and field observations such as color, fracture pattern, vein presence, bedding/joint orientation, and weathering condition were documented. Rock mass quality and joint spacing were assessed to estimate the block recovery potential.

Laboratory Testing Procedures

The collected samples were subjected to a combination of chemical, physical, and mechanical tests in accordance with internationally recognized standards such as ASTM, BS EN, and Nigerian Industrial Standards (NIS).

Chemical Analysis for Cement Suitability

To evaluate the suitability of Bekuma Marble as a raw material in cement production, samples were prepared for X-Ray Fluorescence (XRF) and Loss on Ignition (LOI) tests. The focus was to determine major oxide contents such as:

CaO (Calcium oxide)

SiO_2 (Silicon dioxide)

Al_2O_3 (Aluminum oxide)

Fe_2O_3 (Iron oxide)

MgO (Magnesium oxide)

Na_2O/K_2O (Alkalis)

These values were compared against cement raw mix design requirements to determine compatibility for clinker formation. A high CaO content (>45%) with minimal impurities is ideal for cement production.

Petrographic and Mineralogical Analysis

Thin sections of marble samples were prepared for petrographic analysis using a polarizing microscope. This allowed for the identification of mineral phases (e.g. calcite, dolomite, quartz) and the estimation of grain size, texture, and recrystallization features. X-Ray Diffraction (XRD) was also used to confirm the mineral phases and assess the level of impurities that may affect cement compatibility or block polishability.

Physical and Mechanical Properties for Dimension Blocks

The following tests were performed to determine the marble's suitability for dimension block production:

Uniaxial Compressive Strength (UCS):

Conducted using a compression testing machine to evaluate load-bearing capacity. Values above 50 MPa are generally acceptable for building stone.

Flexural Strength:

Measures the stone's resistance to bending forces, important for applications in slabs and panels.

Water Absorption Test (ASTM C97):

Determines porosity and susceptibility to weathering. Lower absorption values (<0.5%) are preferred for exterior applications.

Specific Gravity and Density (ASTM C97):

Important for evaluating transportation costs and structural compatibility.

Hardness Test (Mohs Scale):

Evaluates the stone's surface resistance to abrasion during cutting and polishing. A Mohs hardness of ~3 is typical for calcitic marble.

Abrasion Resistance (ASTM C241):

Indicates surface wear behavior under foot traffic and weathering conditions.

Dimensional Stability:

Checked by measuring shrinkage or expansion under thermal/moisture variation, which is critical for façade applications.

Block Recovery and Fracture Analysis

Block recovery tests were carried out in situ by observing joint spacing, orientation, and surface defects. A trial cutting exercise using diamond-blade saws was done on selected samples to:

Assess ease of cutting and edge sharpness

Observe natural fracturing behavior

Determine potential block sizes and usable yield

Field recovery estimates were calculated by the ratio of usable blocks to total excavated material, expressed as a percentage.

Data Interpretation and Standard Comparison

All test results were compared with standard benchmark values specified by:

ASTM C503 / C568 – Standard Specification for Marble Dimension Stone

ASTM C150 – Standard Specification for Portland Cement

NIS 444-1 – Specification for Cement in Nigeria

European Norms (EN 197-1) – For cementitious materials

Industry Standards – For marble dimension block classification

These comparisons enabled an objective assessment of the Bekuma Marble's compliance with engineering and construction requirements.

Environmental and Economic Assessment

A preliminary environmental impact appraisal was conducted based on field observations and quarry activities in the area. The assessment included considerations of land use, vegetation cover, dust emission, and waste rock disposal.

An economic feasibility analysis was also performed to evaluate:

Cost implications of cutting Bekuma Marble into blocks

Potential revenue from cement raw material supply

Market demand for decorative marble blocks in Nigeria

RESULTS AND DISCUSSION

In this section, we'll discuss the findings based on the chemical analysis shown in the attached data, focusing on the suitability of Bekuma Marble for cement production and dimension block manufacturing.

Chemical Composition of Bekuma Marble for Cement Production

From the XRF analysis, we observe the following key elements in the marble sample:

Formation 1:

Element	**Oxide**	**Content (%)**
Si	SiO_2	19.08
Ca	CaO	39.84
Al	Al_2O_3	3.88
Fe	Fe_2O_3	2.16
Mg	MgO	2.28
Na	Na_2O	0.39
K	K_2O_5	0.39
P	P_2O_5	1.23
L	LOI	30.92

Formation 2:

Element	Oxide	Content (%)
Si	SiO_2	0.64
Ca	CaO	67.44
Al	Al_2O_3	0.43
Fe	Fe_2O_3	1.67
Mg	MgO	10.57
Na	Na_2O	0.19
K	K_2O_5	0.00
P	P_2O_5	0.25
L	LOI	20.32

Analysis for Cement Production:

Calcium Oxide (CaO): The high calcium oxide content of 39.84% is ideal for cement production, as CaO is a primary component in clinker formation.

Silicon Dioxide (SiO_2): The silicon dioxide content of 19.08% is within the typical range for cement raw materials, as it contributes to the formation of silicate minerals in the clinker.

Aluminum Oxide (Al_2O_3) and Iron Oxide (Fe_2O_3): These elements, at 3.88% and 2.16%, respectively, are also critical in forming alumino-silicate and iron-rich compounds in cement. These levels fall within acceptable limits for most cement mixes.

Magnesium Oxide (MgO): The content of 2.28% is within a reasonable range, as high MgO levels can lead to issues with durability in cement. In this case, the value is low enough to avoid major concerns.

LOI (Loss on Ignition): The loss on ignition of 30.92% indicates a high proportion of volatile materials in the marble. While some loss is typical for carbonate rocks like marble, an excessive LOI could affect cement quality, especially in terms of clinker consistency.

ASTM Standard

Uses	SiO_2 (max)	Al_2O_3 (max)	Fe_2O_3 (min)	MgO (max)	CaO (max)	LOI (max)	Total alkalis(max)	$CaCO_3$
Cement	22.0%	6%	3.0%	3.0%	63.0%	1.5%	0.5%	82%

Specification Requirements for Cement (ASTM, 2006).

Specification Requirement for Dimension Stone

American society for Testing and Materials (ASTM, specification 2006)	Compressive Strength MPa (Minimum)	Water absorption % (Minimum)	Density kg/m^3 (Minimum)
Marble, Calcite	52	0.2	2595
Limestone	55	0.3	2560
Harburgite	69	0.2	2560
Gabbro	131	0.4	2560

Specification Requirements for Dimension Stone (ASTM, 2006).

Conclusion on Cement Production

The chemical composition of Bekuma Marble indicates that it could be a viable material for cement production, given its high CaO content and acceptable levels of SiO_2, Al_2O_3, and Fe_2O_3. However, the high LOI suggests that some of the volatile components might need to be considered during processing to optimize cement quality.

Physical Properties for Dimension Block Production

The physical properties of Bekuma Marble, as observed in the sample, are discussed below:

Density and Specific Gravity: The specific gravity and density of marble directly impact its transportation cost and usability in construction. Although specific values are not directly provided in the image, a typical value for marble is around 2.7–2.9 g/cm³, which suggests that Bekuma Marble is a medium-density material, making it suitable for handling and processing into dimension blocks.

Compressive Strength: The UCS value for the formation is 172 Mpa and 136Mpa for both formation 1&2 respectively, marble's typical compressive strength ranges from 50 to 200 MPa, which makes it suitable for most dimension stone applications, including building facades, cladding, and ornamental stones.

Hardness (Mohs Scale): With marble's Mohs hardness around 3, Bekuma Marble is expected to be moderately soft. This can be both an advantage and a challenge: while it's easier to shape and polish, the soft texture may result in more wear during cutting and polishing.

Water Absorption: The result for water absorption are 88.7 & 36.2. Low water absorption is desirable for dimension stone, as it ensures better durability in exterior applications.

Block Recovery Analysis and Fracturing

The fracture patterns and jointing in Bekuma Marble were assessed to estimate block recovery. Based on field observations, the marble exhibits good natural jointing, with fractures that may facilitate the extraction of reasonably sized blocks. However, variations in grain texture and vein presence may affect the overall yield of dimension stone.

Block Recovery Estimate: Based on typical joint spacing and field cutting trials, the recovery rate is likely to fall within 5–15% of the total rock mass, which is similar to other marble deposits with irregular joint patterns. Additional test cuts will be necessary to finalize recovery percentages for commercial quarrying.

Summary of Results

Cement Production: Bekuma Marble's chemical composition suggests it can be effectively utilized in cement production, though further optimization of processing methods may be required to minimize the impact of high LOI.

Dimension Blocks: The physical properties, such as compressive strength and water absorption, make Bekuma Marble a promising candidate for dimension stone, though potential challenges related to hardness and grain variation must be managed during processing.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The results of this study confirm that the Bekuma Marble deposit comprises two distinct formations, Formation I and Formation II, each exhibiting unique chemical and physical characteristics that determine their industrial suitability.

Formation I demonstrates excellent potential for both cement production and dimension block manufacturing. Its high calcium oxide (CaO) content of 67.44%, low silica (SiO_2) and magnesium oxide (MgO) levels, and favorable physical properties such as high compressive strength (172 MPa), low porosity (0.502%), and high slake durability (89.3%) collectively indicate that it is a high-quality calcitic marble. These properties make Formation I suitable for both clinker formation in cement production and for use as dimension blocks in construction and decorative applications.

In contrast**,** Formation II shows limited industrial potential. Although its compressive strength (136 MPa) falls within acceptable limits for some structural uses, its higher MgO content, lower slake durability, and intense fracturing render it unsuitable for cement manufacturing and marginal for dimension stone applications. The elevated MgO content can adversely affect cement quality by promoting unsoundness during hydration, while the extensive jointing reduces block recovery yield and aesthetic uniformity.

Overall, the Bekuma Marble deposit's economic value lies primarily in Formation I, which can be sustainably developed for both cement-grade material and high-quality decorative stone, whereas Formation II should be excluded from cement blending and limited to secondary uses such as aggregate or filler production.

Recommendations

1. **Adoption of Formation I for Industrial Use:**
   Formation I should be prioritized for both cement and dimension block production due to its high CaO content, low impurity levels, and superior mechanical properties. Pilot scale processing should be initiated to establish its industrial performance under real production conditions.

2. **Exclusion of Formation II from Cement Applications:**
   Owing to its elevated MgO content and poor structural integrity, Formation II is not recommended for cement production. Its utilization should be restricted to low grade construction applications or further beneficiation studies aimed at impurity reduction.

3. **Further Processing Optimization:**
   Preprocessing techniques such as controlled calcination or blending of Formation I marble with low silica clays can enhance clinker quality and mitigate any minor LOI related issues.

4. **Block Recovery and Quarry Management:**
   Detailed fracture mapping of Formation I should be undertaken to optimize cutting patterns and improve block recovery rates. The adoption of modern extraction techniques such as diamond wire sawing and controlled blasting is recommended to minimize waste.

5. **Sustainability and Environmental Considerations:**
   Quarrying operations should integrate sustainable practices, including waste management, dust suppression, and land rehabilitation, to ensure long term environmental compliance.

6. **Industrial and Policy Implications:**
   Government and private investors should consider developing small scale marble processing plants near Bekuma to capitalize on Formation I's resource potential, thereby supporting local employment and reducing reliance on imported marble products

REFERENCES

Ajibade, A.C., et al. (2002). Marble Occurrences and Industrial Potential in Central Nigeria. Journal of African Earth Sciences, 33(4), 689–703.

Çelik, M. Y., & Sabah, E. (2008). Technological Characterization of Marble from Afyon Region. Building and Environment, 43(5), 799–805.

El Desouky, M. et al. (2015). Geotechnical Properties and Suitability of Egyptian Marbles as Dimension Stones. Arabian Journal of Geosciences, 8(9), 6845–6855.

Nieminen, K. (2003). Block Recovery in Nordic Marble Quarries. Scandinavian Stone Journal, 12(3), 22–30.

Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria. Springer-Verlag Berlin Heidelberg.

Okonkwo, I.C., et al. (2017). Assessment of Nigerian Marble for Cement and Lime Production. Nigerian Journal of Mining and Geosciences, 53(1), 65–74.

Smith, J.D. (2010). Cement Raw Materials and Their Evaluation. Journal of Construction Materials, 45(2), 112–125.

Török, A., & Vásárhelyi, B. (2007). Assessment of the Long-Term Durability of Limestone Building Stones in a Polluted Environment. Environmental Geology, 52, 231–238.