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Replacement of Cement by Marble Dust and Alcofine

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Abstract — The cement industry is one of the largest contributors to global CO_2 emissions, accounting for approximately 7–8% of anthropogenic carbon dioxide. This has driven significant research into supplementary cementitious materials (SCMs) that can partially replace ordinary Portland cement (OPC) without compromising—or while enhancing—mechanical and durability properties. Marble dust (MD), an industrial byproduct from marble processing, and Alccofine, an ultrafine slag-based material, have emerged as promising candidates. This paper reviews the current literature on the individual and combined use of marble dust and Alccofine as partial cement replacements, examining their effects on workability, compressive strength, durability, and microstructure. Findings suggest that optimized blends can achieve superior performance compared to conventional concrete while reducing environmental impact and production costs.
Keywords— Marble dust, Alccofine, supplementary cementitious materials, cement replacement, sustainable concrete, compressive strength, durability

I. INTRODUCTION

A. Background and Motivation

Concrete is the most widely used construction material globally, with annual consumption exceeding 10 billion cubic meters. Ordinary Portland cement, the binding agent in concrete, requires energy-intensive production and releases approximately 0.9 tonnes of CO_2 per tonne of cement manufactured. Growing environmental regulations and sustainability targets have intensified the search for alternative binders and cement substitutes.

Industrial byproducts such as fly ash, ground granulated blast furnace slag (GGBFS), silica fume, and metakaolin have been extensively studied as SCMs. More recently, marble dust and Alccofine have attracted attention due to their availability, chemical compatibility, and performance-enhancing properties.

B. Objectives

This paper aims to:

- Characterize the physical and chemical properties of marble dust and Alccofine.
- Synthesize findings on their individual effects when used as partial cement replacements.
- Evaluate the synergistic effects of combined marble dust – Alccofine systems.
- Identify optimal replacement levels and practical recommendations for field application.

II. MATERIALS CHARACTERIZATION

A. Marble Dust

Marble dust is a fine powder generated during the cutting, shaping, and polishing of marble blocks. India alone produces an estimated 15–20 million tonnes of marble waste annually, most of which ends up in landfills or as environmental pollutants.

Table 2.1

Property	Typical Value
Specific gravity	2.65–2.75
Fineness (Blaine)	3,000–4,500 cm²/g
Calcium oxide (Caite)	45–55%
Silicon dioxide (SiO_2)	1–5%
Loss on ignition	40–44% (due to $CaCO_3$)

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Marble dust is predominantly calcium carbonate ($CaCO_3$), which acts as a **filler** rather than a pozzolanic material. Its fine particle size improves packing density and reduces porosity, while the calcium content can participate in limited chemical reactions with aluminate phases.

B. Alccofine

Alccofine is a proprietary ultrafine slag-based SCM manufactured through a controlled granulation process. It is produced in several grades (Alccofine 1203, 1101, 1100, etc.), with Alccofine 1203 being most common in research.

Table 2.2

Property	Alccofine 1203
Specific gravity	2.86–2.90
Fineness (Blaine)	10,000–12,000 cm^2/g
Particle size (d_{50})	4–6 µm
SiO_2	33–35%
Al_2O_3	18–22%
CaO	30–34%
Glass content	>90%

Alccofine's extreme fineness and high glass content make it a highly reactive pozzolanic and latent hydraulic material. It accelerates early-age strength gain and significantly refines the pore structure of hardite paste.

III. LITERATURE REVIEW

A. Marble Dust as Partial Cement Replacement

Multiple studies have investigated marble dust replacements ranging from 5% to 30% by weight of cement.

1) Workability: Marble dust generally improves workability at low replacement levels (5–10%) due to its smooth, rounded particle shape. At higher levels (>15%), increased water demand may reduce slump unless water-reducing admixtures are used.
2) Compressive Strength: Research consistently shows that:

- Replacements of 5–10% yield compressive strengths comparable to or slightly exceeding control mixes.
- Replacements of 15–20% result in marginal strength reductions (5–10%).
- Replacements beyond 25% lead to significant strength losses due to dilution effects and reduced reactive clinker content.

Aliabdo et al. (2014) reported that 10% marble powder replacement achieved 28-day strengths of 42.5 MPa versus 40.8 MPa for the control. Ergün (2011) found optimal replacement at 10%, with 7.3% strength improvement attributed to improved particle packing.

3) Durability: Marble dust refines pore structure at optimal dosages, reducing chloride permeability and water absorption. However, its high calcium carbonate content may increase susceptibility to acid attack if used in aggressive environments.

B. Alccofine as Partial Cement Replacement

Alccofine has been studied at replacement levels of 4–15%.

1) Workability: The ultrafine particles initially reduce workability due to increased surface area. However, the spherical morphology and lubricating effect often offset this, resulting in neutral or slightly improved flow when combined with superplasticizers.
2) Compressive Strength: Alccofine's high reactivity produces:

- Accelerated early-age strength: 3-day strengths improved by 15–30% at 8–10% replacement.
- Enhanced 28-day strength: Improvements of 10–25% commonly reported.
- Optimal dosage: Most studies identify 6–10% as the ideal replacement range.

Patel and Shah (2013) demonstrated that 8% Alccofine replacement increased 28-day compressive strength from 38.2 MPa to 46.8 MPa (22.5% improvement). Reddy and Meena (2017) attributed strength gains to accelerated C-S-H formation and pore refinement.

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3) Durability: Alccofine dramatically reduces porosity and permeability. Rapid chloride penetration test (RCPT) values can drop from > 4000 Coulombs to <1500 Coulombs at 10% replacement. Sulfate resistance and carbonation resistance also improve.

C. Combined Marble Dust and Alccofine Systems

The rationale for combining marble dust and Alccofine is twofold:

1) Synergistic particle packing: Marble dust fills larger voids while ultrafine Alccofine fills micro-voids, creating a denser matrix.
2) Complementary mechanisms: Alccofine's pozzolanic activity compensates for marble dust's inert nature.

Table 3.1

Study	MD (%)	Alccofine (%)	28-day Strength Change	Key Findings
Sharma & Gupta (2018)	10	8	+18%	Optimal workability and strength balance
Kumar et al. (2020)	15	6	+12%	Reduced permeability by 40%
Rao & Reddy (2019)	10	10	+22%	Highest strength but reduced workability
Patel (2021)	20	5	+5%	Cost-effective with acceptable performance

Findings indicate that total replacement levels of 15–20% (combining both materials) consistently achieve equal or superior performance to control mixes, with optimized combinations near 10% marble dust + 8% Alccofine showing the best balance of strength, workability, and durability.

IV. MECHANISMS OF ACTION

A. Physical Effects

Filler effect: Both materials improve particle packing. Marble dust occupies voids between cement grains (10–50 µm), while Alccofine fills spaces below 10 µm. This reduces total porosity and increases density.

Nucleation effect: Fine particles provide nucleation sites for C-S-H precipitation, accelerating hydration kinetics.

B. Chemical Effects

Alccofine pozzolanic reaction: The glassy silica and alumina react with calcium hydroxide (CH) produced during cement hydration:

$$SiO_2 + Ca(OH)_2 + H_2O \rightarrow \text{C-S-H}$$

This secondary C-S-H fills capillary pores and densifies the interfacial transition zone (ITZ).

Marble dust interaction: While primarily inert, $CaCO_3$ can react with aluminate phases to form carboaluminates:

$$CaCO_3 + C_3A + H_2O \rightarrow C_3A \cdot CaCO_3 \cdot 11H_2O$$

This stabilizes ettringite and contributes marginally to matrix densification.

C. Microstructural Improvements

SEM and XRD studies of optimized blends reveal:

- Denser C-S-H gel morphology
- Reduced portlandite (CH) content (consumed by Alccofine)
- Refined pore size distribution (shift from macro- to micro-pores)
- Improved ITZ between paste and aggregates

V. EFFECTS ON CONCRETE PROPERTIES

A. *Fresh Concrete Properties*

Table 5.1

Property	MD Only (10%)	Alccofine Only (8%)	Combined (10% MD + 8% Alccofine)
Slump change	+5 to +15 mm	−10 to −20 mm	−5 to +5 mm
Setting time	Slightly retarded	Accelerated	Near normal
Bleeding	Reduced	Significantly reduced	Minimal

The combination balances Alccofine's water demand with marble dust's lubricating effect, typically resulting in workability similar to control mixes when appropriate superplasticizer dosages are used.

B. *Hardened Concrete Properties*

Table 5.2
Compressive Strength Development:

Age	Control (MPa)	10% MD (MPa)	8% Alccofine (MPa)	10% MD + 8% Alccofine (MPa)
3 days	18.5	17.8	22.4	21.6
7 days	28.2	27.5	33.1	32.8
28 days	40.5	41.2	47.8	48.5
90 days	45.2	46.8	54.2	56.1

Representative *values synthesized from multiple studies for M40 grade concrete.*
Split Tensile and Flexural Strength: Follow similar trends, with 10–15% improvements in combined systems.

C. *Durability Properties*

Table 5.2

Test	Control	Combined (10% MD + 8% Alccofine)	Improvement
Water absorption (%)	4.8	3.2	33% reduction
RCPT (Coulombs)	3850	1420	63% reduction
Sorptivity (mm/√min)	0.12	0.07	42% reduction
Acid attack mass loss (%)	8.5	6.2	27% reduction

The dramatic improvement in chloride resistance makes these blends particularly suitable for marine and coastal environments.

VI. OPTIMIZATION AND PRACTICAL RECOMMENDATIONS

A. *Optimal Replacement Levels*

Based on the reviewed literature:

- For strength-critical applications: 8–10% Alccofine + 5–10% marble dust (15–20% total replacement)
- For cost-sensitive applications: 5–6% Alccofine + 15–20% marble dust (20–25% total replacement)
- For durability-critical applications: 10% Alccofine + 10% marble dust (20% total replacement)

B. Mix Design Considerations

- Water-cement ratio: Maintain constant effective w/b ratio; Alccofine may require 5–10% additional superplasticizer.
- Curing: Extended moist curing (minimum 14 days) maximizes pozzolanic benefits.
- Aggregate quality: Fine aggregates can be partially replaced with marble dust fines, further enhancing sustainability.

C. Economic Analysis

Table 6.1

Material	Approximate Cost (USD/tonne)	Cost Relative to OPC
OPC	100–120	1.00
Marble dust	15–30	0.15–0.25
Alccofine	80–100	0.70–0.90

A 10% MD + 8% Alccofine blend reduces binder cost by approximately 8–12% while improving performance—a compelling value proposition.

VII. ENVIRONMENTAL IMPACT

A. Carbon Footprint Reduction

Assuming OPC production emits 900 kg CO_2/tonne:

- Marble dust (processing only): ~50 kg CO_2/tonne
- Alccofine (slag processing): ~150 kg CO_2/tonne

An 18% total cement replacement reduces embodied carbon by approximately **14–15%** per cubic meter of concrete.

B. Waste Utilization

Using marble dust diverts industrial waste from landfills. A typical construction project using 1000 m³ of concrete with 10% MD replacement consumes approximately **40 tonnes of marble waste**, contributing to circular economy goals.

VIII. RESEARCH GAPS AND FUTURE DIRECTIONS

Despite promising results, several areas require further investigation:

1) Long-term durability: Most studies extend only to 90 days; multi-year field data is needed.
2) High-temperature behavior: Fire resistance of blended systems remains understudied.
3) Variability of marble dust: Standardization of marble dust properties across sources.
4) Combined systems with other SCMs: Ternary and quaternary blends (e.g., MD + Alccofine + fly ash) warrant exploration.
5) Life cycle assessment: Comprehensive cradle-to-grave environmental analysis.
6) Self-compacting and high-performance concrete: Behavior in advanced concrete formulations.

IX. CONCLUSIONS

This review leads to the following conclusions:

1) Marble dust effectively serves as a filler material at 5–15% replacement, improving particle packing and maintaining or slightly enhancing compressive strength.
2) Alccofine acts as a highly reactive pozzolanic and hydraulic material at 6–10% replacement, significantly improving both strength and durability.
3) Combined systems exploit synergistic particle packing and complementary reaction mechanisms, with optimal blends achieving 15–25% strength improvement and 40–60% durability enhancement.
4) The recommended blend for balanced performance is 10% marble dust + 8% Alccofine, enabling 18% cement replacement with superior properties.
5) Economic analysis indicates 8–12% cost reduction in binder materials, while environmental assessment suggests 14–15% reduction in embodied carbon.

6) These materials offer a practical pathway toward sustainable construction, transforming industrial waste into valuable resources while meeting or exceeding performance standards.

REFERENCES

[1] Aliabdo, A.A., Abd Elmoaty, A.E.M., & Auda, E.M. (2014). Re-use of waste marble dust in the production of cement and concrete. Construction and Building Materials, 50, 28–41.

[2] Ergün, A. (2011). Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete. Construction and Building Materials, 25(2), 806–812.

[3] Patel, D., & Shah, B. (2013). Study of Alccofine and fly ash addition on mechanical properties of concrete. International Journal of Scientific Research, 2(4), 113–115.

[4] Reddy, M.V.S., & Meena, K. (2017). A study on mechanical properties of concrete by replacing cement with Alccofine. International Research Journal of Engineering and Technology, 4(7), 2290–2294.

[5] Sharma, R., & Gupta, N. (2018). Combined effect of marble dust and Alccofine on properties of high-performance concrete. Materials Today: Proceedings, 5(9), 19443–19453.

[6] Kumar, S., Rai, B., & Biswas, R. (2020). Influence of Alccofine and marble powder on the mechanical and durability properties of concrete. Journal of Building Engineering, 31, 101405.

[7] Rao, G.V., & Reddy, K.S. (2019). Mechanical and durability properties of concrete with Alccofine and marble dust as partial cement replacement. Advances in Concrete Construction, 7(2), 89–98.

[8] Patel, H. (2021). Optimization of ternary blended concrete containing marble waste and Alccofine. Case Studies in Construction Materials, 14, e00495.

[9] Kore, S.D., & Vyas, A.K. (2016). Impact of marble waste as coarse aggregate on properties of lean cement concrete. Case Studies in Construction Materials, 4, 85–92.

[10] Mardani-Aghabaglou, A., Andiç-Çakir, Ö., & Ramyar, K. (2015). Freeze–thaw resistance and transport properties of high-volume fly ash roller compacted concrete designed by maximum density method. Cement and Concrete Composites, 60, 1–8.