

Experimental Investigation on the Use of Marble Powder and Alum Sludge as Partial Cement Replacement in Sustainable Concrete

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Abstract—Alum salts are commonly used in the water industry to promote coagulation in the production of clean drinking water, which results in the generation and accumulation of 'waste' by-product 'alum sludge in large volumes. Effective and efficient management of alum sludge in an economically and environmentally sustainable manner remains a significant social and environmental concern with ever increasing demand for potable water as a result of rapidly escalating world population and urban expansion. Various intensive practices have been employed to reuse the alum sludge in an attempt to figure out how to fill the gap between successful drinking water treatment process and environmentally friendly alum sludge management for over the years. To control its effect, we have to use this waste. In this study the effect of using marble powder and alum sludge as constituents of fines in concrete by partially reducing quantities of cement has been studied in terms of the relative compressive strength and flexural strength. Partial replacement of cement and usual fine aggregates by varying percentage of marble powder and sludge reveals that increased waste marble powder or waste sludge ratio result in increased workability, compressive strengths and flexural strengths of the mortar and concrete. It can save cost. It saves cement and thus reduces global warming; one gives most critical problems of today.

Index Terms—Marble Powder, Alum Sludge, Compressive Strength, Flexural Strength.

I. INTRODUCTION

Concrete is the most widely used construction material due to its strength, durability, and versatility. However, the major binding material used in

concrete, Ordinary Portland Cement (OPC), is responsible for considerable environmental impacts. Cement manufacturing releases a large amount of carbon dioxide due to the calcination of limestone and high energy consumption, thereby contributing significantly to global warming.

In parallel, industrial growth has led to the generation of enormous quantities of waste materials. The marble industry produces large amounts of marble powder during cutting and polishing operations, while water treatment plants generate alum sludge as a byproduct of coagulation and sedimentation processes. Disposal of these wastes occupies valuable land and poses serious environmental threats.

The utilization of such waste materials in concrete presents a dual advantage: reduction in cement usage and effective waste management. In this context, marble powder, rich in calcium carbonate, can act as a micro-filler, while alum sludge, containing alumina and silica, can contribute to strength development. This research aims to experimentally investigate the performance of concrete incorporating marble powder and alum sludge as partial replacements of cement, thereby promoting sustainable and eco-friendly construction.

II. LITERATURE REVIEW

- Concrete made with waste marble powder and supplementary cementitious material for sustainable development (Ashish & Deepankar Kumar, 2019) studied partial replacement of sand with marble powder (up to 15%) and use of

supplementary cementitious materials (metakaolin, silica-fume). They found that when marble powder replaced sand (rather than cement), and with SCMs added, durability improved; no adverse effect noted in setting and soundness of blended cement pastes.

Several conference/journal papers from 2019 (for example in JETIR) looked at marble dust/powder replacing cement or sand. One review state that replacement of cement by marble powder up to around 10% gives beneficial or comparable compressive strength; beyond that strength declines. No strong open access paper found in 2019 specifically for "alum sludge" as cement replacement. Remarks for 2019

The evidence is largely for marble powder as replacement for sand or fine aggregate, or sometimes cement, but fewer rigorous studies for alum sludge. Optimal levels of replacement appear to cluster around 5-10% for cement substitution of marble powder.

Gaps: workability & long-term durability often not fully addressed; interactions with cement chemistry (pozzolanic vs inert behavior) still ambiguous.

➤ Effect of Marble Waste Powder as Cement Replacement on The Concrete Mixes (Elsageer et al., 2020) replaced cement by marble powder at 0, 2.5, 5, 7.5, 10% by weight (w/c=0.48) and tested compressive strength at 3, 7, 14, 28 days. They found that higher levels caused a noticeable drop in strength; only 2.5% replacement achieved compressive strength very close to control.

Evaluating the Strength and Durability of M40 Concrete Incorporating Marble Dust (Naik, 2020) for M40 grade concrete replaced cement by marble powder at 5, 10, 15, 20, 25%. They found 10-15% substitution feasible: strength was maintained and, in some cases, increased (~20% increase reported for 10-15% replacement) though these results may require local context scrutiny. Still very limited specific work referenced for 2020 in the open literature for alum sludge as cement replacements.

The marble powder literature shows mixed results: very low replacement (2.5-5%) safe; some aggressive studies claim 10-15% or more. But strength tends to decline beyond optimum.

Workability, microstructure, cost/CO: savings often not deeply quantified.

For alum sludge, the field remains sparse a research opportunity.

➤ Evaluation of Concrete with Partial Replacement of Cement by Waste Marble Powder (Majeed, Khitab et al., 2021) prepared concrete mixes with 0, 5, 10, 15% replacement of cement by waste marble powder (WMP). They used both destructive and non-destructive tests.

Review articles (e.g., Strength Assessment of Concrete using Marble Waste...) again confirm optimum replacement around ~10% for cement substitution; beyond those diminishing returns. Properties of concrete incorporating alum sludge in concrete (Kaish et al., 2021) investigated use of alum sludge as partial replacement of fine aggregate (not cement) in concrete.

Physical and Mechanical Properties of High-Performance Concrete with Alum Sludge as Partial Cement Replacement (Owaid et al., 2021) examined alum sludge (AS) replacing cement at 0-15% in HPC (w/b=0.33). They found 6% replacement improved compressive & splitting tensile compared to control; higher replacement beyond-12-15% tended to drop.

Remarks for 2021

The marble powder studies continue to indicate ~10% as a "safe" region for cement replacement.

For alum sludge, the beginning of credible data appears: small % replacements (6%) show promise in high-performance concretes.

➤ Alum sludge/alum waste

Effect of alum sludge on concrete strength and two-way behavior (Ahmed et al., 2022) studied normal concrete where cement was partially replaced by alum sludge; they examined density and compressive strength at ages 7 and 28 days.

Influence of alum sludge ash and ground granulated blast-furnace slag on cementitious composites (Ng et al., 2022) investigated alum sludge ash (ASA) replacing cement in blends with GGBFS. They found improved performance in some cases, Remarks for 2022.

Research for alum sludge becomes more robust: more substitution trials, blends with other SCMs (GGBFS) appear.

Key findings: modest replacement (10%) of cement with alum sludge/sludge ash may offer mechanical strength comparable to control; above that

performance may decline unless activation/processing is optimized.

III. PROBLEM STATEMENT

The report identifies the high cost of conventional construction materials and the environmental issues associated with cement production, which contributes to greenhouse gas emissions. With over 3.3 billion tons of cement consumed globally, the need for sustainable alternatives is critical. The project aims to explore the feasibility of using industrial waste, such as marble powder and alum sludge, to partially replace cement in concrete, thereby reducing reliance on natural resources and minimizing environmental degradation.

IV. OBJECTIVE AND SCOPE OF STUDY

The primary objectives of the study include investigating the effects of marble powder and alum sludge on the mechanical properties of concrete, determining the optimal replacement percentages, and assessing the ecological footprint of the modified concrete. The study focuses on various replacement levels (0%, 5%, 10%, 15%, and 20%) for both materials and aims to evaluate their impact on compressive and flexural strength, workability, and overall sustainability.

V. METHODOLOGY FOR MATERIAL SELECTION AND TESTING

The methodology section outlines the materials used in the study, including coarse and fine aggregates, cement, water, marble powder, and alum sludge. The report details the process of collecting and processing these materials, including the grinding of alum sludge to achieve the desired fineness. The concrete mix design follows a nominal mix for M20 grade concrete, with specific calculations for the quantities of each material required for testing. The study employs various tests, including workability, compressive strength, and flexural strength tests, to evaluate the performance of the concrete mixtures.

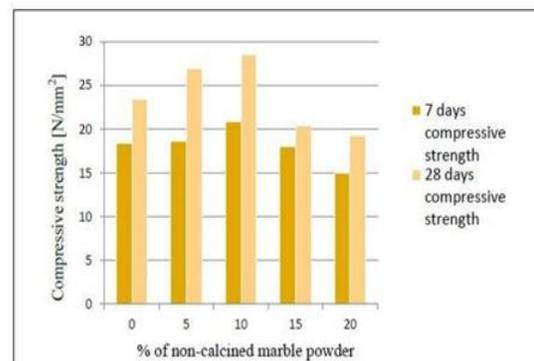
Workability and Compressive Strength Testing

Marble powder [%]	Slump cone value [mm]
0	62
10	64
15	64
20	61

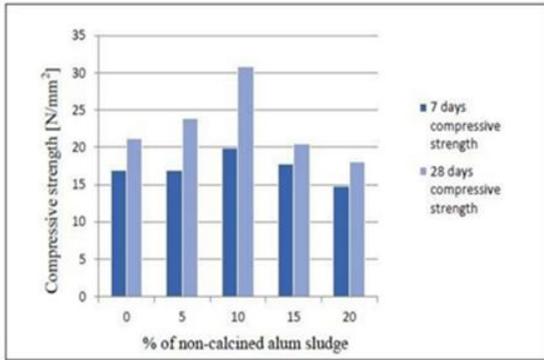
Alum Sludge [%]	Slump cone value [mm]
0	71
10	73
15	73
20	72

The workability of the concrete mixtures is assessed using the slump cone test, with results indicating that the addition of marble powder and alum sludge affects the workability positively.

Replacement by weight [%]	Avg. 7 days compressive strength [N/mm ²]	Avg. 28 days compressive strength [N/mm ²]
0	18.36	23.41
5	18.59	26.96
10	20.88	28.44
15	18.07	20.30
20	14.96	19.25



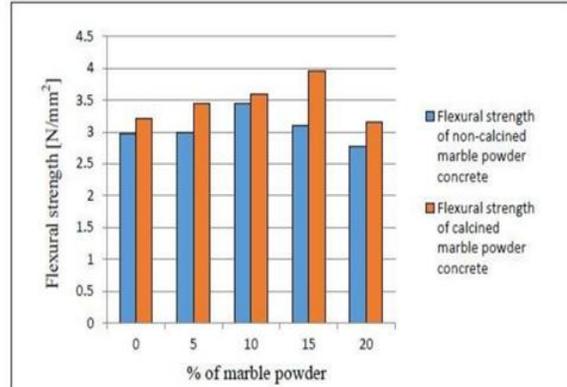
Replacement by weight [%]	Avg. 7 days compressive strength [N/mm ²]	Avg. 28 days compressive strength [N/mm ²]
0	16.88	21.25
5	16.98	23.89
10	19.89	30.79
15	17.85	20.55
20	14.75	18.11



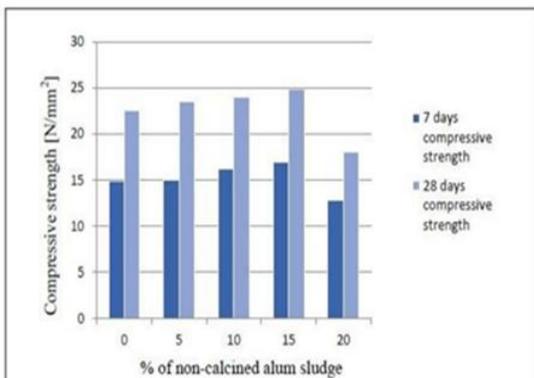
data on the compressive strength results, demonstrating the effectiveness of using these waste materials in concrete.

Flexural Strength Testing Results

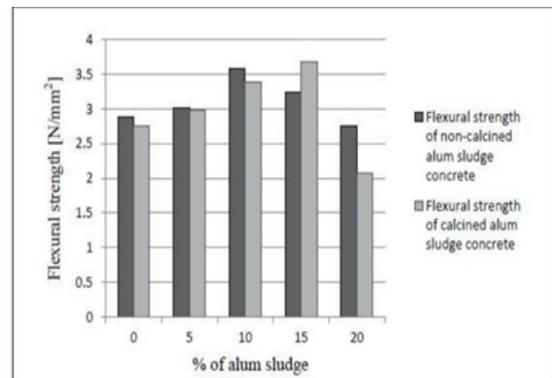
Flexural strength tests are conducted on beam specimens to evaluate the bending performance of the concrete mixtures. The results indicate that the flexural strength improves with the addition of marble powder and alum sludge.



Replacement by weight [%]	Avg. 7 days compressive strength [N/mm ²]	Avg. 28 days compressive strength [N/mm ²]
0	14.85	22.58
5	15.05	23.52
10	16.25	23.95
15	16.98	24.85
20	12.85	18.0



Constituent	CALCINATION		NON CALCINATION		
	Replacement by weight [%]	Avg. 28 days flexural strength [N/mm ²]	Constituent	Avg. 28 days flexural strength [N/mm ²]	
Marble Powder	0	3.21	Marble Powder	0	2.98
	5	3.45		5	3.0
	10	3.6		10	3.45
	15	3.95		15	3.1
	20	3.15		20	2.78
Alum Sludge	0	2.75	Alum Sludge	0	2.89
	5	2.98		5	3.01
	10	3.38		10	3.58
	15	3.68		15	3.25
	20	2.08		20	2.75



The compressive strength tests reveal that the optimal replacement percentages for marble powder and alum sludge are 10% and 15%, respectively, as these levels yield the highest compressive strength values at both 7 and 28 days of curing. The report presents detailed

VI. CONCLUSION

The comparison of conventional RMC with marble powder and water treatment sludge leads to the following conclusions:

- The EF of conventional RMC was estimated as 0.0295 gha/m³. Its compressive strength was 23.41 N/mm², and the production cost was 72.78 \$/m³ (6009.81 Rs/m³).
- The EF of RMC for 10% cement replacement with sun-dried marble powder was 0.0256 gha/m³ (i.e., 13.14% less than the conventional ready-mix concrete). Its compressive strength was 28.44 N/mm², and the production cost was 68.60 \$/m³ (5664.7 Rs/m³).
- The EF of RMC for 15% cement replacement with calcined marble powder was 0.0294 gha/m³ (i.e., 0.27% less than the conventional RMC). Its compressive strength was 29.33 N/mm², and the production cost was 70.57 \$/m³ (5827.3 Rs/m³).
- The EF of RMC for 10% cement replacement with sun-dried WTS was 0.0255 gha/m³ (i.e., 8.81% less than the total EF of conventional RMC). Its compressive strength was 30.79 N/mm², and the production cost was 69.4 \$/m³ (5730.7 Rs/m³).
- The EF of RMC for the 15% cement replacement with calcined WTS was 0.0287 gha/m³ (i.e., 4.26% less than the total EF of conventional RMC). Its compressive strength was 24.85 N/mm², and the production cost was 70.2 \$/m³ (5796.8 Rs/m³).
- The performance of calcined marble powder and WTS presents better results; however, sun-dried marble powder and WTS are recommended for concrete production to avoid the unwanted presence of moisture, which can reduce the material's shelf life and alter the desired workability. The use of waste (marble powder and water treatment sludge) in the concrete may also improve the ESI of the ready-mixed plant. The study suggested that the ecological footprint of concrete reduces by using (sun-dried and calcined) marble powder and WTS as cement replacement. Using low-environmental and low-cost materials may also improve the ESI of a construction industry.

REFERENCES

- [1] Deepankar Kumar Ashish, "Feasibility of waste marble powder in concrete as partial substitution of cement and sand amalgam for sustainable growth", *Journal of Building Engineering*, Publisher: Elsevier, January 2018
- [2] Wackernagel, M.; Rees, W. *Our Ecological Footprint: Reducing Human Impact on the Earth*; New Society: Gabriola Island, BC, Canada 1996.
- [3] Akhtar, N.; Ahmad, T.; Husain, D.; Majdi, A.; Alam, T.; Husain, N.; Wayal, A.K.S. Ecological footprint and economic assessment of conventional and geopolymer concrete for sustainable construction. *J. Clean. Prod.* 2022, 380, 134910.
- [4] V. M. Sounthararajan and A. Sivakumar, Effect of The Lime Content in Marble Powder for Producing High Strength Concrete. *ARNP Journal of Engineering and Applied Sciences*, VOL. 8, NO. 4, APRIL 2013 ISSN 1819-6608.
- [5] Prof. Veena G. Pathan, Prof. Md. Gulfarn Pathan, Feasibility and need of use of waste marble powder in concrete production *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
- [6] Er: Raj.p.singhkushwah, Prof (Dr.) Ishwar Chand Sharma, Prof (Dr.) PBL Chaurasia (2015) Utilization of "Marble Slurry" In Cement Concrete Replacing Fine Aggregate. *American Journal of Engineering Research (AJER)* e-ISSN: 2320-0847 p-ISSN: 2320-0936 Volume-04, Issue-1, pp-55-58
- [7] Noha M. Soliman, Effect of using Marble Powder in Concrete Mixes on the Behavior and Strength of R.C. Slabs, *International Journal of Current Engineering and Technology* ISSN 2277-4106 Vol.3, No.5 (December 2013)
- [8] Jamshidi, Mehrdadi N, Jamshidi M. "Application of sewage dry sl 40 fine aggregate n concrete. "Journal of Environmental studies, vol 37.dec (2 Roccaro p1 (2015) "Use of sludge from water and wastewater treatment plants in the production of concrete"