Evaluating the Impact of Barium Oxide on the Mechanical, Rheological, and Color Characteristics of Self-Compacting Concrete

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ABSTRACT

Colored self-compacting concrete (SCC) has gained significant attention in modern architecture due to its unique characteristics and visual appeal. The primary objective was to determine its impact on the rheological, mechanical, and chromatic properties of concrete and to identify the optimal dosage for its application. In this study, barite oxide was added to the mix design at dosages of 0%, 2.5%, 5%, 7.5%, and 10% by weight of cement. The experimental program included assessing the rheological behavior of the SCC, compressive strength at various ages, tensile strength, initial and final water absorption, and an analysis of chromatic indices. The results indicated that by increasing the barite oxide content from 0% to 10%, the blocking ratio in the L-box test decreased from 0.93 to 0.81, representing a reduction of 12.9% compared to the control sample. Furthermore, the lightness value (L*) of the concrete surface decreased from 82% to 73%, indicating a darkening effect of approximately 11%. Compressive strength results demonstrated that at lower dosage ratios, the filler effect and the resulting densification of the concrete microstructure led to a relative improvement in strength, with the sample containing 5% barite oxide exhibiting the best performance (performance index of 0.699). At concentrations exceeding 7.5%, a reduction in strength was observed, attributed to increased heterogeneity within the cement matrix. The findings suggest that the use of approximately 5% barite oxide can establish an optimal balance between workability, mechanical strength, and color intensity in self-compacting concrete.

KEYWORDS

Self-compacting concrete (SCC), Barium oxide, Colored concrete, Rheological properties, Compressive strength, Color analysis.

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1. Introduction

Colored self-consolidating concrete (SCC), owing to its high flowability, superior surface finish, and flexibility in realizing complex architectural forms, offers a modern, cost-effective alternative to traditional cladding materials in urban environments [1, 2]. Beyond aesthetic considerations, colored concrete must also maintain adequate durability and mechanical performance [3]. Unlike expensive synthetic pigments, which exhibit limited stability in the alkaline concrete matrix and under UV radiation [4, 5], natural mineral pigments such as barite offer high chemical, thermal, and light stability. Their fine particles can also fill capillary pores, enhancing matrix compactness and durability; the availability of domestic reserves further supports their economic feasibility [6–11]. The objective and novelty of this study are to use barite in white-cement-based SCC to achieve a stable, muted pink-to-peach color range while simultaneously evaluating its effects on fresh-state workability, mechanical properties, durability, and microstructure, without compromising strength [12].

2. Methodology

This study investigated the effects of adding barite oxide at 0, 2.5, 5, 7.5, and 10% of the cement weight on SCC properties. The white cement content (450 kg/m³), limestone powder content (90 kg/m³), water-to-cement ratio (0.45), and superplasticizer dosage (3% by weight of cementitious materials) were kept constant in all mixtures. The experimental program comprised five mixtures and 75 specimens. Fresh-state performance was evaluated using the slump-flow, T_{50}, V-funnel, L-box, U-box, and J-ring tests. Compressive strength was measured at 7, 28, and 90 days, and splitting tensile strength was determined using the Brazilian test at 90 days.

Table 1. Mix proportions used for the experimental program

Name	Cement	Limestone powder	Coarse aggregate	Fine aggregate	Barite oxide	Cementitious materials	Water	Superplasticizer
	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³
CONTROL	450	90	1100	600	0	450	202.5	13.5
KZ-2.5%	450	90	1100	600	11.2	461.2	202.5	13.8
KZ-5%	450	90	1100	600	22.5	472.5	202.5	14.1
KZ-7.5%	450	90	1100	600	33.7	483.7	202.5	14.5
KZ-10%	450	90	1100	600	45	495	202.5	14.8

3. Results and Discussion

The results showed that adding barite oxide as a mineral pigment to self-consolidating concrete (SCC) provides a balance between appearance, workability, and strength. As the barite oxide content increased, the workability of fresh concrete gradually decreased, which was attributed to increased interparticle friction and paste viscosity. The L-box blocking ratio decreased from 0.93 in the control mixture to 0.81 in the mixture containing 10% barite oxide. This trend was consistent with the findings of Golshan et al. (1402), who reported that adding mineral powders with a high specific surface area increases plastic viscosity and reduces the blocking ratio [13]. However, the loss of flowability in barite-containing concrete was less pronounced than in concretes containing synthetic pigments such as iron oxide, which has high water absorption [18]. All mixtures containing up to 7.5% barite oxide remained within the EFNARC limits. At low barite oxide contents, its filler effect led to a relative increase in compressive strength, consistent with previous findings on the use of iron oxide and mineral pigments as fillers [20, 22]. At contents above 5%, matrix heterogeneity and possible weakening of the paste–aggregate interfacial transition zone initiated a decline in strength. This decline was observed beyond 7.5% and was consistent with previous findings that high pigment contents weaken the paste–aggregate bond in colored concrete [24]. Micronized barite oxide produced a stable pink-to-peach color. Analysis of the colorability index showed that the color change was nonlinear and reached saturation beyond a certain dosage. In addition, barite oxide contents of up to 5% resulted in more favorable permeability and water absorption, which was attributed to the mineral's compatibility with the chemical structure of cement. These properties make barite-containing colored concrete suitable for precast elements, urban furniture, and architectural façades, particularly in moderately humid environments and

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projects where visual appearance is a priority. When barite oxide contents exceed 7.5%, the superplasticizer dosage should be adjusted to compensate for reduced flow and prevent blocking in sections with congested reinforcement. Further investigation of long-term color durability under weathering and ultraviolet radiation is recommended. These results were obtained from laboratory testing of a specific mixture design using specified materials and cannot be directly generalized to SCC mixtures with different designs or materials. Applying the findings to other projects requires re-evaluation using the materials selected for each project.

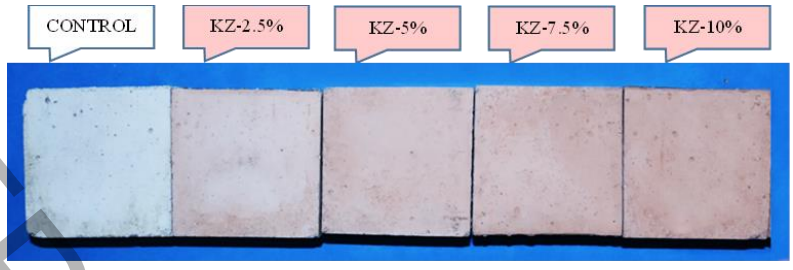


Figure 1. Comparison of the coloration of specimens containing different barite oxide contents.

4. Conclusions

1. The compressive strength of the specimens containing 2.5% and 5% barite oxide increased compared with the control specimen, an improvement attributed to the filler effect and the reduction in capillary porosity within the cement paste microstructure.

2. At dosages exceeding 7.5%, the compressive strength exhibited a declining trend, which was attributed to the formation of matrix heterogeneity and the weakening of the interfacial transition zone between aggregate and paste.

3. Colorimetric analysis indicated that increasing the barite oxide dosage reduced lightness (L^*) from 82% in specimens with low replacement levels to 73% at higher levels, representing an approximately 11% darkening of the concrete surface.

4. Water absorption results demonstrated that within the optimum dosage range, the permeability of the concrete was lower than that of colored specimens containing organic pigments, yielding a denser matrix microstructure.

5. The incorporation of 5% barite oxide as an effective mineral filler concurrently enhanced mechanical, rheological, and colorimetric indices without exceeding standard operational limits.

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