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# The use of Wollastonite to enhance the mechanical properties of mortar mixes

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## HIGHLIGHTS

- Wollastonite is an inert mineral which can enhance mortar micro structure.
- The incorporation of Wollastonite in mortar as partial substitute of sand enhances its strength.
- Replacement of sand with Wollastonite powder delays the initial setting time.
- Incorporation of Wollastonite powder enhances the drying shrinkage resistance of mortar mixes.

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## ABSTRACT

The effect of using mineral Wollastonite powder as a partial substitute of cement or sand in Portland cement mortar mixes was studied. Seven different mixes of mortar incorporating Wollastonite as a partial substitute of cement or sand with replacement levels of 10%, 20%, and 30% were prepared and tested. Initial setting time was measured and a delay up to 60% was observed for mortar mixes with 30% sand replacement while mortar mixes with cement replacement showed a marginal increase up to 5%. Compression test results showed a 45% increase in compressive strength due to 20% sand replacement. Flexural strength was enhanced by 28% by the same batch. The effect of Wollastonite in resisting drying shrinkage was investigated and test results showed a reduction in length change for both mortar mixes with 30% cement replacement and 30% sand replacement up to 47% and 44% respectively.



## 1. Introduction

When selecting a cementitious composite, particular attention should be paid to its durability; one of the main factors that influences durability is shrinkage and the resultant cracks formation. Many researchers [1–5] have investigated shrinkage types and different factors affecting shrinkage; reduction in the concrete volume due to moisture loss, rate of evaporation, bleeding shrinkage rate, w/b ratio, tensile strength, modulus of elasticity, creep relaxation, and degree of restraint. Many approaches were proposed to minimize the shrinkage cracking behavior such as adding shrinkage reducing admixtures (SRA) or improving curing conditions. Unfortunately SRA have been reported to have negative side effects; reduction in the degree of hydration of the cement, significant reductions in mechanical strength, and delays in setting time [6]. Combination of expansive admixtures and SRA has been tested and synergistic effect has been reported justifying its use in shrinkage control [6,7].

Replacing sand or cement in Portland cement mortar with a natural mineral such as Wollastonite represents a challenge. Wollastonite is a naturally occurring acicular, white mineral with needle-like crystals. The chemical composition of Wollastonite is β-CaSiO3. Wollastonite is categorized according to its particle size; particles with sizes from 25 to 150 μm are considered as microfibers, less than 25 μm are considered as powder and more than 150 μm are considered fibers. Recently Wollastonite has been commonly known worldwide for its major industrial importance. It is used primarily in ceramics, friction products, paint filler, and plastics. Unfortunately its uses in the construction field are very limited, although its acicular shape and durability improvement behavior allows it to compete with other materials. In the recent years studies have been made to prove its significance in construction field.

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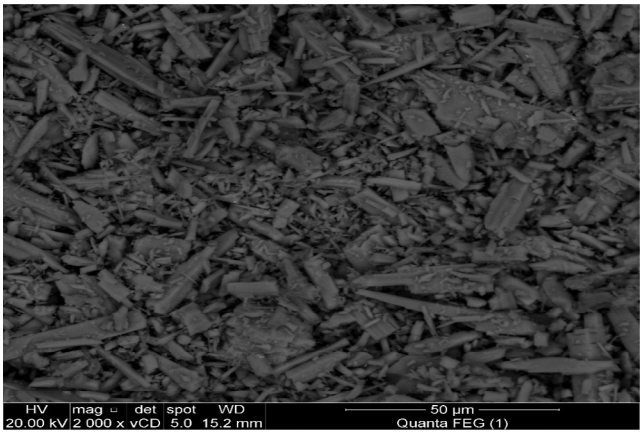
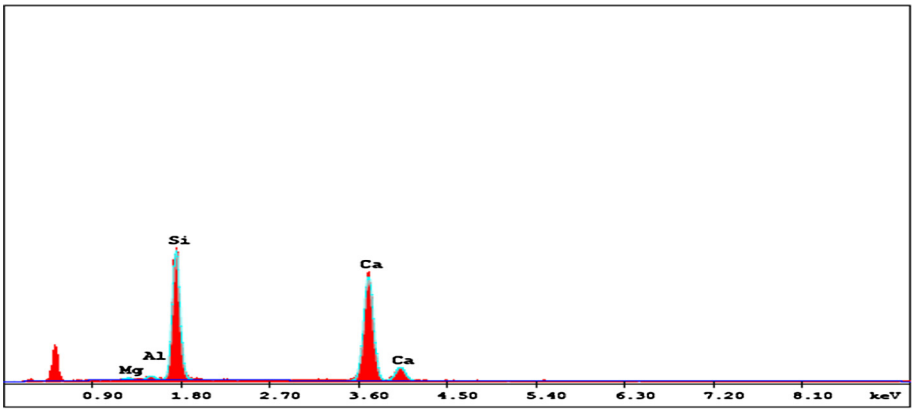



**Fig. 1.** Microstructure of Wollastonite powder (×2000).

The effect of using both SRA and Wollastonite micro-fibers on ultra-high performance concrete was investigated by Soliman and Nehdi [2]. They concluded that the delayed cracking time through reducing the developed capillary stresses and consequently shrinkage strains lead to a lower mass loss, less drying shrinkage and reduction in SRA leaching. Kalla et al. [8] reported that when replacing 55% to 60% of the cement with combination of Wollastonite and fly-ash in concrete mixes of 0.45 and 0.5 w/b ratios, improvements in shrinkage resistance and reduction in permeability were observed. Mathur et al. [9] used same combination of Wollastonite microfibers (M400) and fly ash as partial substitute of cement/sand and noticed reduction in water absorption and drying shrinkage. Hamedanimojarrad [10] and Galea et al. [11] used powder Wollastonite with 4 μm particle size as an admixture and found that increasing the concentration of Wollastonite decreases the amount of drying strain. Many researchers have studied the effect of using Wollastonite on the mechanical properties of cementitious composites. Low and Beaudoin [12] investigated flexural toughness improvement of Portland cement-based binders reinforced with natural Wollastonite micro-fibers with median particle size of 55 μm combined with silica fume. They reported that the optimum concentration of Wollastonite micro-fibers for enhancing the flexural toughness would range from 2 to 15%. In another study [13], Low and Beaudoin investigated the stability of Wollastonite micro-fibers with a concentration of 11.5% after exposure to prolonged hydration in a highly alkaline environment. They concluded that the contribution of Wollastonite micro-fibers to the strengthening process is apparently unaffected by aging. Dey et al. [14] used combination of Wollastonite and silica fume for micro (850–2000 μm) and sub-micron (33–55 μm) Wollastonite fibers up to 20% cement replacement. They reported that Wollastonite fibers moderately increase compressive strength, and significantly increase fracture toughness resulting in enhanced ductility and improved resistance to crack growth. In other study, Kalla et al. [15] reported improvements in strengths for concrete mixes containing Wollastonite as cement replacement with concentration range of 10–15%. They also reported that Wollastonite made the mix more densified leading to a durable matrix. The effect of Wollastonite on the setting time of ordinary Portland cement pastes and mortars was investigated by Ransinchung et al. [16]. They noted that the substitution of cement with Wollastonite powder causes increase in initial and final setting times up to 25% and 27.5% respectively, beyond decreasing effect appears. They also reported that incorporating micro-silica with Wollastonite as substitution of cement significantly increases the compressive strength.

**Table 1**
Physical properties of Wollastonite powder.

| Property | Median Particle Size μm | Surface Area ($m^2$/gm) (BET) | Moisture (%) | Morphology | Specific Gravity | Bulk Density g/$cm^3$ | | Coefficient of Expansion mm/mm/°C |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Loose | Tapped | |
| Typical Value | 9.5 | 1.6 | 0.1 | Acicular | 2.9 | 0.65 | 1 | $6.5 \times 10^{-6}$ |




| Element | Wt % | Mol % | K-Ratio | Z | A | F |
|---|---|---|---|---|---|---|
| MgO | 0.63 | 0.91 | 0.0020 | 0.9904 | 0.5363 | 1.0064 |
| Al2O3 | 1.47 | 0.84 | 0.0051 | 0.9612 | 0.6773 | 1.0122 |
| SiO2 | 51.56 | 50.05 | 0.1883 | 0.9892 | 0.7861 | 1.0047 |
| CaO | 46.34 | 48.20 | 0.3061 | 0.9616 | 0.9611 | 1.0000 |
| Total | 100.00 | 100.00 | | | | |

**Fig. 2.** Chemical composition of Wollastonite NYAD M400 using XRD test.