CIVIL ENGINEERING APPLICATION AND EARLIER RESEARCH ON WOLLASTONITE – A REVIEW

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Abstract — When impure dolostone or limestone is subjected to high temperature and pressure it will leads to formation of Wollastonite. Wollastonite is a Calcium silicate mineral ($CaSiO_3$) that may contain small traces of other minerals like Iron, Magnesium, and Manganese substituting for Calcium which is available in many location below the ground surface. It is a versatile industrial mineral, find its applications in many engineering industries with its properties like high brightness and whiteness. It has the property of low moisture and oil absorption with low volatile content. In this paper, various applications, research of Wollastonite in the field of civil engineering like concrete technology, geotechnical engineering, and also in various construction materials are discussed. The feature scope of Wollastonite has also been discussed.

Index Terms — Wollastonite, limestone, minerals, civil engineering. Geotechnical engineering.

I. INTRODUCTION

Wollastonite is an industrial mineral containing chemicals like calcium, silicon and oxygen. Molecular formula of Wollastonite is $CaSiO_3$ and its approximate theoretical composition consists of 48.28% of CaO and 51.72% of SiO_2. Natural Wollastonite may contain traces or minor amounts of various metal ions such as aluminum, iron, magnesium, potassium and sodium. Wollastonite is infrequently found in pure form and generally contains other minerals namely calcite, garnet and dropsied as gangue minerals or impurities those removed during extraction process. Optimum performance can be obtained by properly toning suitable pairing agent at the suitable concentration level to the polymer formulations. It possesses properties like lower moisture content and oil absorption with low volatile content. Surface modification of Wollastonite enhances its physical properties. It also results in improved processing and improved dispersion if implemented in resin. Wallostonite find it's plenty of applications which includes valid like ceramics, paints etc.

II. ABBREVIATIONS AND ACRONYMS

LOI – Loss-on-Ignition, WMF – Wollastonite Mineral Fibre, UCC – Unconfined Compressive strength, CBR – California Bearing Ratio.

III. APPLICATIONS

Wollastonite is a mineral blessed with many unique characteristics. Till 1970, the primary use of Wollastonite was as a decorative stone. Since the past 4 decades, one of the uses has been as a replacement for asbestos in products like insulating board and panels, paint, plastics, roofing tiles, and in friction devices such as brakes and clutches. Wallostonite is one of the most versatile functional filler and reinforcement agents. Wollastonite increases the performance of products like polymers, plastics, paints and coatings, construction materials, friction devices, ceramic, etc. It also been employed for metallurgical applications.

CERAMICS

Wollastonite is utilized in a list of ceramic applications including ceramic glazes, enamels, frits, fluxes and in sanitary wares. As Wollastonite being a calcium silicate rich mineral, it contributes calcium in ceramic glaze mixes. Wollastonite is a source of CaO for alkaline glaze to improve the strength of glaze products. Some grades of Wollastonite has low Loss-on-Ignition (LOI) property. In Such grades of Wollatonite, LOI may be less than 1%, which reduces gas evolution during firing and attributes in smooth surface with diminished pin hole problems. In ceramic industry Wollastonite's needle-like structure improves earlier plastic strength and reduces cracking and warping especially during rapid heating and cooling of Façade and floor tiles. Wollastonite has a low sintering temperature compared to that of most natural frits. Approximately the temperature ranges between 990°C and 1200°C. When sufficient Wollastonite is added to ceramic material, the firing temperature can be decreased, and the baking duration greatly concise to one rapid low temperature bake. It results in saving of fuel and reduction of production costs. At the same time the mechanical properties are enhanced and it leads to products of good quality.

Wollastonite is widely used as a flux in the steel casting process and in the production of paints. In paints, Wollastonite provides hardening, low oil absorption, and other benefits. In textured coatings, like stucco also Wollastonite been employed. Wollastonite is also used in the manufacture of adhesives, joint compounds, refractory brick materials, and rubber. All grades of Wollastonite are used in the production of plastics, including nylons, polyesters, polyurethanes and poly ureas.

PAINTS AND COATINGS

In coatings, Wollastonite particles with its fine needle-like mineralogical structure, act as flattening agent and allow paint to settle down after appliance in order to produce dry film of uniform thickness. Wollastonite's interlocking properties improve toughness and durability of the coating with excellent tone preservation, clean, and weather resistance. High whiteness and brightness property of Wollastonite reduce pigment load and typically very low oil absorption, reduces the volume of binder required and contributes to lower coloring pigment input costs. Wollastonite also acts as a pH buffer for improved Tin-Stored paint stability over long period. The needle-like structure and alkaline nature of Wollastonite also make it an ideal auxiliary pigment in industrial coatings and primers for better resistance against corrosion. When Wollastonite is used as a filling agent in paint, brightly colored paint with superior quality can be obtained. The paint containing

Wollastonite will result in good uniform coating and will have good resistance against weathering agents like rain, storm, etc. White Wollastonite is a good raw material for high quality white and pastel coating. It is easy to apply with a smooth surface.

CONSTRUCTION

In the construction field, Wollastonite has been recognized as a substitute for asbestos in fire-resistant building products. As a functional additive, Wollastonite increases flexural and impact strengths. Wollastonite's low thermal conductivity and high aspect ratio structure extends its possibility to utilize for fire resistant. Wollastonite is useful in interior and exterior construction boards, roof tiles, shaped insulation products, sheets, panels and sidings.

TEXTURE FINISHING

Wallostonite is employed for textured coating like stucco. It imparts crack resistance, reinforcement, and high brightness to the surface. Thus texture finishing using wallostonite is more suitable for exterior portions. Due to its brightness property it may also be used for interior surface coating.

IV. OTHER APPLICATIONS

METALLURGICAL APPLICATIONS

Wollastonite has been honored in metallurgy, due to its low water solubility, low loss on ignition & its Ca–Si ratio. Wollastonite is commonly added into formulated powders for steel casting and welding. Addition of Wollastonite to metallurgical fluxes offers ready fusibility, good insulating and low viscosity properties. As Wollastonite is a naturally available low temperature flux mineral, it has been accepted in fluxing process for the continuous casting of steel. Casting powder formulated with Wollastonite is usually applied when molten steel is poured continuously from a ladle in a perspective of eliminating surface defects, prevention of oxidation of steel, lubricates the mold wall and to shun harmful foreign matters intrusions.

V. EARLIER RESEARCH

WOLLASTONITE IN CONCRETE

Renu Mathur et al. in the year 2007, studied the effects of Wallostonite on cement concrete and cement-fly ash concrete. It includes incorporating Wollastonite as partial substitute of cementitious material and sand respectively. Studies show that replacement with wallostonite by 10% in concrete mixes enhances it's compressive strength by 28 - 35% and flexural strength (36-42%) at 28 and 56 days respectively. By incorporation of Wollastonite, reduction in water absorption, drying-shrinkage and abrasion loss of concrete, and enhancement in durability against alternate freezing-thawing and sulphate attack were observed. Because of high concrete strength and abrasion resistance, a better utilization of concrete cross section is possible. Alternatively, thickness of pavement slab can be reduced by incorporation of Wollastonite micro-fibres in concrete mixes.

Control mix (A) was designed for 420 kg/cm^2 compressive strength at 28 days with the required materials namely cement, sand and aggregates. Incorporation of fly ash in green concrete made concrete mix (B) more workable while addition of Wollastonite decreases the workability of concrete mix. It necessitated the use of plastisizer for required workability attainment. Comparing strength results of control mix with that of cement-fly- ash concrete mix (B), there was reduction in 28 day compressive and flexural strengths. Thereafter at 56 day, due to pozzolanic action of fly ash, both compressive and flexural strengths were at par with the control mix. In mix C (Cement + Wallostonite), there was no significant reduction in compressive strength, but increase (14-20%) in 28 and 56 day flexural strength were observed. Comparing mix D (cement-fly ash + Wallostonite) with mix B, there was gain (28-35%) in 28 and 56 day compressive strength and increase (36-42%) in 28 day and 56 day flexural strength. In mix E, there was gain (32 %) in 28 day compressive and increase (37%) in flexural strength at 56 day.

Improvement in compressive strength of concrete by incorporation of Wollastonite can be attributed to the modification in microstructure of transition zone in the vicinity of Wollastonite. Inclusions have an effect on pore distribution and large increase of pore volume (0.5-0.1 µm) has been reported by addition of Wollastonite in cement matrix. Multiple cracking of cement matrix in post-peak load region and fibre pullout from fractured surface were regarded as the cause of improved ductility and flexural strength of cement matrix reinforced with WMFs. Increase in flexural strength can also be attributed to high modulus of elasticity (200 GPa) of Wollastonite.

Shashi Kant Sharma et al., in the year 2013 have used Wollastonite in mortar and concrete mixes for repair works suffer from debonding and spalling of concrete layer. The major reasons often cited for debonding and spalling of repairs are differential thermal movements, elastic incompatibilities, shrinkage stresses, and occasional impact; rebar corrosion, substrate deficiencies, frost action, and poor workmanship. These same reasons are responsible for cracks in an otherwise, a simple concrete pavement topping. Given these reasons for spalling and debonding of repairs, durable thin repairs (less than 25 mm thick) are particularly difficult to achieve. For a durable repair,the desired characteristics of the repair material include low permeability, a high tensile strength, adequate impact resistance, sufficient deformability (ductility), high fracture toughness, low shrinkage, good dimensional stability, good abrasion resistance, and most of all, a strong tensile and shear bond with the base concrete. For thin repairs, however, the maximum dimensions of both the aggregate particles and the fibers have to be limited. Consequently, for thin repairs, the use of cements concrete and mortars reinforced with microfibers is conceivable. The cylindrical specimens were used for compressive strength tests, the prisms were tested for flexural strength. IS 516:1959 was followed to perform both compression and flexural strength test. Compression strength test was performed on three cube samples per mix and their average value was taken as compression strength of mix. Modulus of rupture was obtained using the prisms supported over a simply supported span of 400 mm, at 28 and 56 days. Loads were applied at middle third points. In terms of percentage strength gain with age, it was found that, with an increment in Wollastonite micro fiber content, there was an apparent increment in flexural strength whereas compression strength found large decrement, when the mixes were compared with normal mix at 56 days. With the introduction of Wollastonite micro fiber (WMF) in concrete, the compression strength and flexural strength do show increment, but it may reduce at higher Wollastonite micro fiber content, due to higher cement replacement.

Rakesh Kumar in the year 2016 analysed the application of Wollastonite mineral fibre for the manufacturing of pavement concrete. Wollastonite mineral fibre (WMF) was used to replace 10% and 20% of sand while fly ash was used to replace 20% of cement of the control concrete. The influence of the addition of WMF and the combination of WMF and fly ash on the fresh as well as hardened state properties of concrete mixtures was evaluated. The fresh properties of concrete that is the slump and fresh density and hardened state properties i.e. compressive strength, flexural strength, and abrasion resistance of concrete mixtures were determined. The study suggests that the addition of

WMF significantly reduces the slump of fresh concrete mixes but increases the density, compressive strength, and flexural strength of hardened concrete. It further shows that the combination of fly ash and WMF (fly ash as a replacement of cement and WMF as a replacement of sand) has an synergic effect on the enhancement of flexural strength which gives a possibility to reduce concrete pavement slab thickness such pavement is more economical and durable than that constructed with conventional concrete.

The workability or consistency of fresh concrete mixes is measured in the term of slump. Further, it can be noticed that the 10% and 20% addition of Wollastonite fibre as a replacement of sand has similar effect. However, in comparison with control the addition of Wollastonite fibre as a replacement of sand enhances the compressive strength in the range of 26-33%.The increase in flexural strength of concrete mixes containing WMF and the combination of WMF with fly ash ranges from 20% to 30% with reference to controlled ones.

IN SOIL STABILIZATION

V. Mohanalakshmi et al., in 2016 studied the effect of wallostonite in Geotechnical engineering. The study involved stabilization of red soil by addition of Wollastonite for various percentages such as 5, 10, 15, and 20. Red soil has been collected at Annur and the properties of red soil (unaltered) is found and then the Wollastonite is added to the red soil, then the properties and strength of soil is found by conducting various experimental investigation. The results show that upto 15% addition of Wollastonite, properties like UCC, California Bearing Ratio (CBR) and Dry density get increased and further addition of wallostonite effects decrease of above mentioned parameters. This study showed that Wollastonite has a big impact in stabilisation of red soil and the optimum percentage of Wollastonite suitable for red soil has been found to be 15%.

VI. RESULTS, DISSCUSSION AND CONCLUSION

Table 1 Effects of Addition of Wollastonite

Sl.No	Material under consideration	Properties Considered
1.	Concrete	1.Slump value 2.Compressive strength 3.Flexural strength 4.Split Tensile strength
2.	Soil	1. Maxium dry density 2. UCC 3. CBR 4. shear strength

The above results show that the application of Wollastonite in Civil engineering material like concrete and geotechnical practice like soil stabilization is more suitable and reliable for required properties enhancement.

Hence the application of Wollastonite may be carried out in sub branches of Civil Engineering like Pavement engineering, Geotechnical engineering, Concrete Technology based on suitable codes.

VII. FUTURE SCOPE

The implementation of Wollastonite can be further extended in Concrete technology and Geotechnical engineering. In soil mechanics this research may be prolonged in various other types of soils. In addition to individual utilisation of Wollastonite, it may be added together with some pozzolanic materials like Fly ash, etc in a view of getting good results. It is concluded based on the effects of Wollastonite and Fly ash in concrete.

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