LIMESTONE POWDER USE IN CEMENT AND CONCRETE

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INTRODUCTION

A filler is a very finely-ground material, of about the same fineness as portland cement. Owing to the physical properties of filler, there is a beneficial affect on some properties of concrete, such as workability, density, permeability, and capillarity therefore structure bleeding, and cracking tendency [1].

The use of filler in cement is a common practice in European countries, especially in France. This type of cement can lead to technical, economic and ecological benefits. Among the technical advantages are the control of bleeding in concrete with low cement content, an increase of early strength, a reduced sensivity and poor curing [2].

The addition of limestone reduces the initial and final setting time, as well as porosity, whereas free lime and combined water increase with increasing limestone content [3]. The quality of the limestone filler affect the performance of the cement in concrete and the water demand of the cement [5].

Limestone filler affects the crystallization nucleus for the precipitation of CH. These effects produce an acceleration of the hydration of cement grains [6, 7].
LIMESTONE POWDER USE IN CEMENT AND CONCRETE

LIMESTONE

Limestones are sedimentary rocks primarily of calcium carbonate. Limestones are generally obtained from the calcareous remains of marine or fresh water organisms embedded in calcareous mud. They change from the soft chalks to hard crystalline rocks [8].

According to Lea [8] the use of limestone as a concrete aggregate has sometimes been suspect on account of the unsuitability of the poorer grade rocks, and also because of a widespread fallacy that limestone concrete is less resistant to the action of fire than concrete made from other aggregates. He suggested that the use of limestones might not be beneficial in concrete products, which are to be cured in high-pressure steam.

Limestone Powder as a Filler in Cement and Concrete

Filler

Filler are usually chemically inert but there is no disadvantage if they have some hydraulic properties or if they enter into detrimental reactions with the products of reactions in the hydrated cement paste [1].

According to Neville [1] filler can be naturally occurring materials or processed inorganic mineral materials. They have uniform properties and fineness. They must not increase the water demand when used in concrete, unless used with a water-reducing admixture, or adversely affect
the resistance of concrete to weathering or the protection against corrosion which concrete provides to the reinforcement. Clearly, they must not lead to a long-term retrogression of strength of concrete, but such a problem has not been encountered.

Because the action of limestone fillers is physical, they have to be physically compatible with the cement in which they are included. For example, at high filler contents, the cement must have a much higher fineness than usual [1].

**Limestone Powder as a Filler In Cement**

According to Livesy [5] limestone-filled cements have been developed in Europe during the last twenty years. They are now being standardized in Europe (CEN) and the UK (BSI). A working party jointly set up by the British Cement Industry and the Building Research Establishment has investigated the composition and performance of these cements.

The use of portland cement containing limestone filler is a common practice in European countries, especially in France. This type of cement is formulated to achieve certain goals in the technical, economic, and ecological fields. Among the technical benefits are the increase of early strength, the control of bleeding in concrete with low cement content and the low sensitibility to the lack of curing [2].

“Although ENV 197-1: 1992 limits the filler content to 5 per cent, it allows the use of limestone up to 35 per cent, provided the remaining cementitious material is portland cement only. This cement is known as portland L limestone cement (Class II/B-L). As limestone is in effect a type of filler, the limestone cement can be said to have a filler content of up to 35 per
cent. It can be expected that, for some purposes, blended cements with a filler content of 15, or even 20, percent are likely to be popular in the future” [1].

Experience in the development and use of filler cements has led to the identification of the most suitable properties for the limestone filler. Limiting values for critical properties have been set in the draft standards to ensure adequate performance. The purity of the limestone should be greater than 75% by mass of Calcium Carbonate content [5].

**Performance of Limestone-Filled Cements**

Limestone filler improves the hydration rate and increases the strength of cement compounds at early ages [9]. Limestone filler does not have pozzolanic properties, but it reacts with the alumina phases of cement to form an Afm phase (calcium monocaboaluminate hydrate) with no significant changes on the strength of blended cement [6].

According to Levisy [5] portland-filler cements can be manufactured to meet the requirements of strength classes 32.5, 42.5, and 52.5 the higher early strength variants for this classes. In order to achieve optimum results consideration has to be given to the suitability of the limestone and the composition and fineness of the cement. In particular the effect of limestone on the water demand of the cement affects its performance in concrete and this cannot always be determined from standard cement tests at constant water: cement ratio.

Except for severely aggressive environments, the use of blends of portland cement (CEI 42.5) with limestone fillers offer, within specific limits of blending, and a reliable way to
perform rheologically. In order to perform at the same strength and durability as conventional mixtures, the use of water-reducing admixtures is a must for these filler blended cement in concrete [10].

**Limestone Powder as a Filler in Mortar**

Nehdi et al. [11] have reported that the effect of limestone microfiller replacement of cement on the mechanical performance and cost effectiveness of low w/c ratio superplasticized portland cement mortars was investigated. They also demonstrated that limestone microfiller replacement of cement did not significantly affect the strength of mortars at early ages up to about 10 to 15% by volume. Higher levels of limestone microfiller caused significant strength losses, which were more significant in the silica fume mixes. At later ages, limestone microfiller replacement of cement beyond 10 to 15% caused strength losses, which were more significant.

**Limestone Powder as a Filler In Concrete**

Nehdi et al. [12] presented Limestone powder was to improve the cost effectiveness of cement, to substitute limestone for gypsum as a set regulator, to improve the workability and stability of fresh concrete, and in some instances to improve durability.

Uchikawa et al. [13] studied the hydration reaction of cement, hardened structure and pore structure in concrete prepared by substituting a large quantity of mineral powder including fly ash, slag, limestone and silicious stone for part of fine aggregate in concrete and the relationships between the substitution of those mineral powders and the physical properties of concrete. They also observed increase in viscosity and decrease in fluidity of concrete by the
substitution of the mineral powder for part of fine aggregate are mainly caused by the increase of fine particles non-existent in fine aggregate.

Shi et al. [14] carried out an investigation to determine the compounding effect of silica fume (SF) with phosphorus slag (PS) or limestone powder (LS). The compound powders of PS with SF lower plastic viscosity and yield stress of fresh concrete, but increase the slump and promote continuous flowability of concrete greatly. However, the compounding of LS with SF increases the yield stress, but decreases both slump and slump flow of concrete, although the viscosity remains broadly unchanged compared with the concrete containing LS only. They presented that rheological property can be highly correlated with the surface characteristic of each component of the compound powders.

**Chemical Effects of The Use of Limestone Powder in Cement and Concrete**

**Chemical Effects of The Use of Limestone Powder in Mortar**

Menendez et al. [15] studied the benefits of limestone filler (LF) and granulated blast-furnace slag (BFS) as partial replacement of portland cement are well established. They reported that LF addition to portland cement causes an increase of hydration at early ages inducing a high early strength, but it can reduce the later strength due to the dilution effect. On the other hand, BFS contributes to hydration after seven days improving the strength at medium and later ages. Mortar prisms in which portland cement was replaced by up to 20% LF and 35% BFS were tested at 1, 3, 7, 28 and 90 days. They also demonstrated that the use of ternary blended cements (PC-LF-BFS) provides economic and environmental advantages by reducing portland cement production and CO₂ emission, whilst also improving the early and the later compressive strength.
Limestone fillers alter composite cements both physically and chemically. They increase density and make the cement more reactive. The reactivity of limestone fillers determines the consumption of calcite the formation of calcoaluminates, the accelerating effect on the hydration of C₃A, C₃S or CA in the high alumina cements, the changes in the C-S-H, the birth of an “aurèle de transition” between the filler and the cement paste, are all facts specific of the reactivity of limestone fillers. Finely ground quartz can be classified as on inert filler because it does not effect these properties [10, 16, 17, 18].

Hornain et al. [19] reported the diffusion of chloride ions in mortars as influenced by the use of limestone powder as a filler. All mixtures were prepared at a fixed water-ratio of 0.55. Test results showed that the diffusion coefficient of chloride ions was reduced with the use of limestone filler.

**Chemical Effects of The Use of Limestone Powder in Concrete**

Heikal et al. [3] studied the effect of substitution of limestone for Homra in pozzolanic cement. They presented that the addition of limestone reduces the initial and final setting time, as well as total porosity, whereas the free lime and combined water increase with limestone content. Limestone fills the pores between cement particles due to formation of carboaluminate, which may accelerate the setting of cement pastes. The addition of limestone filler to neat cement pastes and mortars reduces the diffusion coefficient of chloride ions. They also reported that the amount of limestone increases the heat of hydration, as well as the free lime and compressive strength while the total porosity decreases at early ages.
Bonavetti et al [2] demonstrated that the effect of limestone filler (up to 20%) on the degree of hydration, the volume of hydration products, and the optimal replacement of limestone filler in cement pastes at different w/cm ratios (0.25-0.50). The results showed an increase in the degree of hydration in very low w/cm ratio paste when the limestone filler content is increased. Concrete mixtures (w/cm = 0.30 and 0.34) were made to determine the compressive strength. They also presented that addition of limestone filler in concrete effects acceleration of hydration, dilution, and increase of effective w/c ratio.

Finely divided mineral admixtures can also exert what is often called the “filler effect,” This effect can also contribute to compressive strength in addition to that of its pozzolanic reaction products. Some-what related to this, there has recently been a move in the U.S. to allow the cement producer to intergrind up to 5% limestone (on weight of portland cement) because of its strength enhancement when the cement is used in mortars and concrete. It was first thought that the added finely divided limestone contributed strength strictly through the filler effect. Now there is revealed that that it can react with the latter to form tricalcium carboaluminates analogous to ettringite and its monosulfate form which would account for the increase in sulfate resistance of the cement [20, 21].

**Durability of Concrete with Addition of Limestone Powder**

Gonzales and Irassar [22] studied the addition of limestone filler affect the sulfate performance of blended cements. Test was carried out in mortars containing one type II cement and two type V portland cements with different C₃S contents. Limestone filler was used as 0%, 10%, and 20% of replacement by cement weight. Test result showed the replacement of low
C₃A portland cement with limestone microfiller can significantly affect the sulfate resistance of composed cement.

Sawicz and Heng [23] studied the effect of powdered limestone and water-cement ratio (w/c) on the durability of concrete immersed in a sulphate solution (5% Na₂SO₄). A beneficial influence of powdered limestone on the sulphate resistance of concrete was observed for w/c < 0.60. For w/c > 0.60, the powdered limestone showed almost no effect on sulphate resistance of concrete.

The transformation of ettringite to monosulphate and hemi-sulphate was prevented by addition of limestone powder [23, 24, 25]

Sawicz and Heng [23] reported that the addition of limestone powder to cement changes the phase composition of pastes in comparison with pastes without addition. Tests were carried out investigations limestone powder prevents the transformation of ettringite to sulfoaluminates (monosulphate, hemisulphate and solid solutions), instead of which carboaluminate phases more resistant to sulphate attack (monocarbonate, hemicarbonate) are formed.

**Autogenous Shrinkage of High-Flow Concrete with Limestone Powder**

Kato et al [26] studied the influence of limestone powder content on setting, strength and autogenous shrinkage of high-flow concrete were discussed. Ordinary portland cements were used with additions of 0, 10, 20 and 30 wt % limestone powder. Test results showed setting of concrete were accelerated by additions of limestone powder, strength decreased with the
additions of limestone powder, but a slight decrease of compressive strength was found with addition of 10 wt % and compressive strength of concrete increased linearly with decreasing the porosity with or without additions of limestone powder. They observed autogenous shrinkage decreased with increasing the additions of limestone powder in the early stage, but kept increasing for long time with limestone powder. They suggested that the increase of autogenous shrinkage due to additions of limestone powder in the long stage related to Monocarbonate.

CONCLUDING REMARKS

In general limestone powder filler in cement and concrete effects acceleration of hydration, dilution of cement paste, increase of effective \( w/c \) ratio and increases the strength at early ages \([2]\). The addition of limestone powder filler to fine cement pastes and mortars reduces the diffusion coefficient of chloride ions \([3]\).

Sawicz and Heng \([23]\) have reported that the addition of limestone powder to cement changes the phase composition of pastes in comparison with pastes without addition. They also demonstrated limestone powder prevents the transformation of ettringite to sulphaaluminates (monosulphate, hemisulphate and solid solutions), instead of which carboaluminate phases more resistant to sulphate attack (monocarbonate, hemicarbonate) are formed.

The use of limestone powder in cement and concrete provides economic and environmental advantages by reducing portland cement production and CO\(_2\) emission, as well as improving the early and the later age compressive strength \([2, 15]\)
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