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A Review on The Effect of The Raw Mill Dust on The Properties of Concrete

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A B S T R A C T

The main environmental impact of concrete comes from raw mill dust and carbon dioxide emissions during cement production. This paper reviews the effect of raw mill dust on the mechanical properties of concrete, the development and improvement of concrete mixtures, and the use of raw mill dust as a partial cement substitute to eliminate the environmental impact of raw mill dust. This dust is used to reduce energy consumption and carbon dioxide emissions. This is achieved by replacing cement with raw mill dust used in the cement industry. To study the effect of using raw mill dust as a partial cement substitute in concrete, special attention was paid to the physical and chemical properties of the material. This paper aims to evaluate the potential of using this dust, a by-product of the cement industry, to improve concrete performance while reducing environmental impacts. It also evaluates the effect of different proportions of mill dust as a partial cement substitute on compressive strength, tensile strength, and workability. The results showed that incorporating mill dust in specific proportions improved some mechanical properties, such as increased long-term compressive strength, while slightly reducing tensile strength compared to conventional concrete. The addition also contributed to improving the sustainability of concrete by reducing cement consumption and carbon dioxide emissions.

1. Introduction

Nineveh Governorate, located in northern Iraq, is one of the regions rich in natural resources, making it a center for producing high-quality cement. However, the cement production process is accompanied by major environmental challenges, most notably the dust resulting from the grinding of raw materials. These processes produce large amounts of fine particles that spread in the air, leading to negative effects on the environment and public health. In light of the environmental and economic challenges that are facing the construction industry, it has become necessary to search for sustainable solutions to improve resource efficiency and reduce the environmental impacts resulting from the use of traditional materials. Among these solutions, the use of mill dust as a partial substitute for cement stands out, as this dust is a by-product of the cement industry and has pozzolanic properties that enhance the performance of concrete due to its low cost and simple access to raw materials, concrete is the generally often used building material in the world. However, Cement output is an energy-intensive and carbon dioxide-intensive process, both of which are detrimental to the surroundings [1, 2]. As a result, scientists want to use less energy and carbon emissions in the cement production process by using less cement in concrete [3,4]. Because of its widespread availability and advantages for the economy and environment, limestone powder has drawn a lot of interest as a partial substitute for cement since the early 1990s [5], [6], [7]. The successful application of limestone powder as a supplementary cementitious material (SCM) has thus been investigated in several studies [6], [7], [8], [9], [10] by evaluating the impact of the limestone particle size and contents on the workability, hydration products, porosity, strength, and durability of ordinary Portland cement (OPC) concrete. Finer limestone powder improves the workability of OPC concrete by morphological, filler, and dilution effects, according to earlier evaluations Furthermore, it is advantageous to substitute OPC with up to 15% high blain fineness limestone to increase the compressive strength of OPC concrete through filler, nucleation, and chemical effects.

2. History of Limestone Modified Concrete

For many years, limestones, also called calcium carbonate or $CaCO_3$, have been an essential part of concrete. In Europe, using limestone powder as a substitute for cement dates back to 1965. In Europe, Portland-limestone cement (PLC) is widely used by inter-grounding limestone with cement clinker (Schmidt, 1992). The use of inter-ground limestone in the ASTM (American Society for Testing and Materials) standard and Portland cement specification has recently been included in U.S. standards. Up to 5% limestone powder is permitted in Type I cement according to ASTM C150 (ASTM C150, 2015) [11], The normative specification for blended hydraulic cement is ASTM C595, which permits up to 15% of the blended cement's mass to be composed of limestone as Type IL (ASTM C595, 2015) [12]. Portland limestone cements are manufactured in small quantities and are not readily accessible in the United States, despite the ASTM standards permitting their usage. Similar to other pozzolanic ingredients, limestone can be added to concrete by directly integrating the limestone powder into the mixing procedure. The limestone powder can be included with the concrete during batching, and this method is an alternative to inter-grounding the limestone with the cement. When batching concrete and substituting limestone powder for cement, the two materials are manufactured independently and have distinct physical characteristics. Controlling the limestone powder is necessary since its particle size, surface area, and dispersion might vary

3. Limestone Powder in Concrete

3.1. Use of limestone powder in mixes

Luc Courard (2018) [13] over roughly 28 days at room temperature, sufficiently fine limestone will aid in certain void-filling reactions that assist in lowering porosity and boosting strength. It will initially function as an inert filler if it is excessively coarse. Although it will contribute to some (although limited) hydration processes if pulverized to a fineness similar to cement, its impact on lowering water demand is minimal. Of course, workability and compressive strength will be enhanced when limestone is ground to a finer consistency than clinker.

The impact of limestone powder (LP) as a compensating material with varying cement amounts on compressive and tensile strengths both before and after exposure to high temperatures, such as 200, 400, and 600 degrees Celsius, was investigated by Abdul Hakim Hamed (2009) [14]. According to this study, limestones have an impact on tensile and compressive strengths. When the quantity of limestone was more than half the weight of cement, it also demonstrated its impact on the characteristics. The results demonstrated a reduction in compressive and tensile strengths in various forms following exposure to high temperatures.

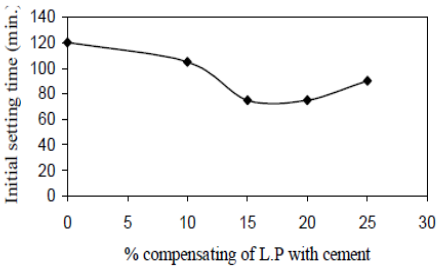

Fig. 1. average of three samples illustrates the impact of partially substituting LP for cement on [13].

This covers the impact of high temperatures on this kind of concrete as well as the impact of limestone powder (CaCO3) as a compensating material with cement on compressive and tensile strengths.

Fig.1 (average of three samples) illustrates the impact of partially substituting LP for cement on the first configuration time and slump. For the limestone powder cement that was rewarded at amounts of (10,20) %, the initial setting time dropped to roughly 75 minutes, and at the maximum amount of compensation (25%), it increased to 90 minutes. The extent of calcareous filler chemical activity is generally acknowledged to be extremely restricted because fillers typically replace cement; there is a dilution effect, and the cement paste decreases these affected at the time of initial setting. This is in addition to the fact that calcareous fillers have a relatively limited chemical interaction with hydrated products. It has been demonstrated that a chemical reaction of calcite CaCO3 with C3A reactivity appears.

Portland cement was partially substituted with natural pozzolana (NP) and limestone filler (LF) by M. Ghrici, S. Kenai, and M. Said-Mansour (2007) [15]. At 2, 7, 28, and 90 days, he examined the flexural and compressive strength of specimens in which up to 20% LF and 30% NP were substituted for Portland cement. After examining these specimens, it was discovered that using triple blend cement enhances both the long-term compressive and flexural strength as well as the early life. Additionally, durability was enhanced. It was shown to have improved resistance to sulfate, acid, and chloride ion penetration. The compressive and flexural strengths of tested composite cement mortars are shown in Table 1.

In 1:2.75 mixes with a water/cement percentage of 0.70, the impact of three fillers—ground limestone, dolomite, and basalt—on cement strength was investigated. These fillers ranged in fineness from 1150 to 11200 cm2/g and in proportion from 10 to 40% by weight of cement. The findings demonstrated that these fillers had an impact on strength by speeding up the cement's hydration. Strength increased with both filler amount and fineness, and the improvement was consistent across all fillers.

Table 1. Flexural and compressive strengths of composite cement mortars that have been tested.

Compressive and flexural strengths of tested composite cement mortars										
OPC	NP	LE	Flexural strength (MPa)				Compressive strength (MPa)			
			2 days	7 days	28 days	90 days	2 days	7 days	28 days	90 Days
100	00	00	4.1	6.3	8.9	8.9	16.6	38.1	45.3	47.8
90	00	10	4.3	5.5	7.8	8.5	17.4	35.4	43.3	46.6
80	00	20	3.6	5.2	7.6	8.3	13.7	31.7	39.4	44.7

The enhanced mixture density (i.e., lower air content) brought about by the addition of fillers contributes to this strength improvement (Soroka and N. Setter, 1977). [16]

The impact of varying limestone proportions on the compressive strength, water penetration, absorption, electrical resistance, and quick permeability to chloride of concrete created by mixing Portland cement and limestone mixture was described in a paper by Aquino Carlos and Miura Hiroaki,[17]. The concrete was tested at 28, 90, and 180 days. The following percentages of cement weight were used to replace limestone: 0%, 5%, 10%, 15%, and 20% by mass. A constant total binder concentration of 350 kg/m3 is associated with water/ (limestone + clinker) or w/w ratios of 0.37, 0.45, and0.55.

All things considered; the findings demonstrate that Portland cement lime concrete (PLC) with up to 10% limestone offers comparable qualities to Portland cement concrete.

4. Origin of Raw Mill Dust Powder

Grinding process of raw materials Raw materials such as limestone and clay are ground in rotating mills During the grinding process, very fine dust is generated as a result of friction and crushing. The generated dust is spread in the air inside and around the mill due to the nature of the mechanical process. The use of specialized devices such as bag filters or electrostatic precipitators to capture the flying dust.

Some mills are equipped with built-in air suction systems that directly extract the dust during the grinding process. Separation of dust from the air the collected dust is separated from the air using cyclones or fine particle separation systems. The collected dust is stored in silos or special bags and is then transported for use. The chemical proportions are shown in Table 3.

Table 1. Summary of key findings from previous studies

Reference	Main results
Luc Courard (2018)	The study showed that fine limestone powder helped reduce porosity and increase the strength of concrete over 28 days at room temperature. If the limestone is too coarse, it acts as an inert filler, while when ground to a fineness similar to cement, it contributes only minimally to hydration processes. Grinding limestone to a fineness higher than clinker was also shown to enhance workability and compressive strength.
Abdulhakim Hamed (2009)	The study examined the effect of using limestone powder as a partial cement replacement on the compressive and tensile strength of concrete before and after exposure to high temperatures (200, 400, and 600°C). The results showed that limestone affects concrete strength, particularly when used at a concentration exceeding 50% of the cement weight. Exposure to high temperatures also reduced concrete strength by varying degrees.
Miura Hiroaki and Aquino Carlos	The study investigated the effect of different proportions of limestone powder on the compressive strength, water permeability, absorption, electrical resistance, and chloride permeability of concrete mixed with Portland cement. Samples were tested after 28, 90, and 180 days, with cement replaced at 0%, 5%, 10%, 15%, and 20%. The results showed that concrete containing 10% limestone possessed
M. Said-Mansour M. Ghrici, S. Kenai (2007)	This study investigated the effect of partially replacing Portland cement with both natural pozzolan (NP) and limestone powder (LF). Cement was replaced with up to 20% limestone powder and 30% natural pozzolan, and the flexural and compressive strengths of the samples were evaluated at 2, 7, 28, and 90 days. The use of triple blend cement improved both short- and long-term compressive and flexural strengths. The durability of the concrete was significantly increased, making it more resistant to deterioration.
N. Setter and Soroka (1977)	The study investigated the effect of using three types of fillers (limestone powder, dolomite, and basalt) on the strength of cement in 1:2.75 mixes with a water/cement ratio of 0.70. The fineness of these fillers ranged from 1,150 to 11,200 cm²/g, and they were used at 10% to 40% of the cement weight. All fillers accelerated the cement hydration process, leading to improved mechanical strength. Increasing the proportion and fineness of the fillers resulted in a consistent improvement in concrete strength.

4.1. Dilution effect

The amount of limestone in the matrix is mostly responsible for its diluting impact. Only a limited portion of LS participates in the reactions because alumina is present in cement in trace proportions. As a result, the amount of cement clinker and hydration products is reduced when a higher percentage of LS is added in place of cement. Furthermore, because LS lacks cementitious or pozzolanic qualities, replacing it the amount of free water is increased with cement. that can react with cement particles—a phenomenon familiar as the dilution effect—all while maintaining the same ratio of water to binder. Numerous investigations have established that this causes the cement's hydration degree to increase [18, 19].

4.2. Filler Effect

The filling action of limestone is significantly influenced by its particle size. The computed packing density of mixes including LS, slag, and cement [20]. Figure 2a shows that the packing density of mixes is less when the LS particle size is bigger or approximate similar to Portland cement,

While Figure 2b shows that the packing density is more when the LS particle volume is softer than that of cement. Suppose the LS particle size is finer than the cement particle. In that case, it will fill the gaps between the cement particles, improve the particle size distribution, and eventually increase the packing density of cement-based composites [21]. Consequently, adding LS to concrete improved its durability and compressive strength while lowering its water need. Even though adding fine LS could fill up the spaces between cement and particles, if the LS particle size is too small, its high particular surface area will despatcher flowability of cement-based compositions. When 3% nano limestone was added to UHPC, the flowability of UHPC dropped by 27%.

4.3. Chemcical effect

Grinding process of raw materials Raw materials such as limestone and clay are ground in rotating mills During the grinding process, very fine dust is generated as a result of friction and crushing. The generated dust is spread in the air inside and around the mill due to the nature of the mechanical process.

Chemical composition	Content (%)
CaO	42.15
SiO2	13.73
Fe2O3	1.69
Al2O3	3.78
MgO	2.72
SO3	0.38

The use of specialized devices such as bag filters or electrostatic precipitators to capture the flying dust. Some mills are equipped with built-in air suction systems that directly extract the dust during the grinding process. Separation of dust from the air the collected dust is separated from the air using cyclones or fine particle separation systems. The collected dust is stored in silos or special bags and is then transported for use. The chemical proportions are shown in Table 3.

5. Action Mechanism Raw Mill Dust Powder in Cement-based Materials

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5.3. Chemical effect

Particle volume, the amount of alumina from C3A and C4AF in cement, and SCMs all have a major impact on the mixture's chemical reaction with LS. The rate at which LS dissolves increases as its particle size increases. Consequently, the pore solution's calcium carbonate concentration rises, enhancing LS's chemical action. Particularly for nano limestone, its surface energy and surface shape vary noticeably as its particle size decreases. and LS's chemical reactivity rises as well. However, the aluminate supplies that C3A, C4AF, and SCMs may offer also improve the LS chemical reaction. When the carbonate ion from LS reacted with the redundant C3A and C4AF to generate carbo aluminate, it was reported that ettringite was stabilized [22]. Additionally, the morphology of C-S-H was altered by the addition of LS, resulting in thicker and shorter CS-H (I) fibers. The chemical impact of limestone in cement-based materials is minimal because of the limited aluminate phase in cement clinker. The chemical action of LS may be enhanced by the extra aluminate in SCMs [23].

6. Mechanical Properties

6.1. Compressive strength

The trace of Limestone powder content on the compressive strength of mortars at various ages is seen in Fig. 3. Using finer LS to fill in the gaps created by cement particles might raise cementitious materials' determination density. Then the compressive strength of self-compacting concrete was enhanced with the addition of ultra-fine LS. At various ages, the compressive strength of concrete with fine LS (5 lm) was higher than that of concrete with coarse LS (10 and 20 lm) [24]. The compressive strength was decreased, and a diluting effect was observed when a significant quantity of fine Limestone powder was substituted for cement. As the LS concentration rose, the compressive strength generally declined, and as Fig. 3 [25] illustrates, the diluting effect of Limestone powder on the compressive strength became increasingly noticeable at early ages. The cement intensity dropped, and the hydration production reduced as

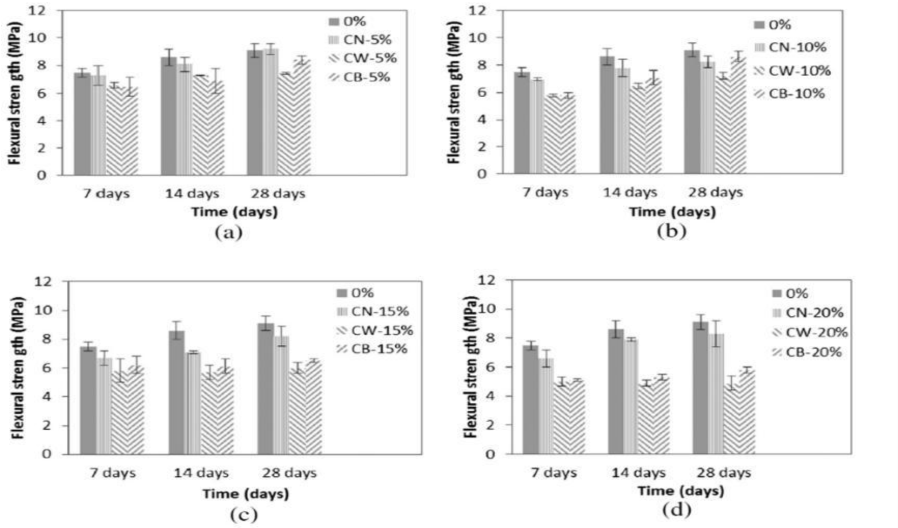

Fig. 1. impacts of LS type and content on concrete's flexural strength. [26]

the Limestone powder content rose. When the LS concentration exceeded 35%,

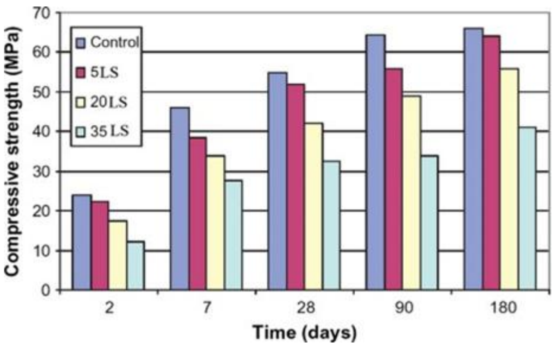

Fig. 2. Impact of LS content on mortars' compressive strength at varying ages [25].

The diluting effect became more apparent [25]. The compressive strength was decreased when 15–45% Limestone powder was added in place of cement. relying on the age and water-to-binder percentage, the capacity reduction of concrete containing LS varied from 9% to 86% Limestone powder may fill the aggregate gap and boost compressive strength when used in place of cement dentifrice or fine aggregate. Though the W/C remained constant, the compressive strengths of concrete were considerably enhanced by using LS for cement paste.

6.2. Flexural strength

LS mostly illustrates filler and mitigation results when used in place of cement; its chemical and nucleation effects on flexural strength are less evident, as shown in Fig.4 The use of nano-limestone, which has particles ranging in size from 15 to 80 nm, in place of cement increased the flexural strength of UHPC. The addition of 3% nano-limestone to UHPC instead of cement increased the material's flexural strength at W/B of 0.16 and 0.17 by 40% and 30%, respectively.

On the other hand, limestone would have a diluting effect if its particle size was comparable to that of cement. Concrete's flexural strength dropped when LS was used in place of cement because the amount of cementing materials fell while the amount of non-cementing materials increased. According to Fig. 3 [26], the flexural strengths decreased as the LS content rose. Concrete without LS had a flexural strength of 9.1 MPa, whereas concrete with 5% and 10% LS had flexural strengths of 7.5 and 7.3 MPa, respectively.

6.3. Water permeability

Concrete's water permeability can be increased, porosity can be decreased, and cement particle spaces can be filled with finer LS. Concrete's water permeability was decreased by substituting LS for cement paste. As the LS content rose, Chen et al. [27] discovered that there was a sharp decline in the water penetration depth, as seen in Fig. 4. It showed that the filler effect of LS significantly reduced the water permeability of concrete when it was utilized in place of 0–8% cement paste. Concrete's pores were filled, the pore structure was fine-tuned, and the permeable pore size was decreased by using LS in place of cement paste. It was also noted that adding LS decreased the concrete's depth of water penetration and that the impact of finer Limestone powder on this depth was more pronounced Filler, nucleation, and dilution effects were observed when a significant quantity of LS was utilized in place of cement.

6.4. Carbonation resistance

using limestone powder (Blaine softness: 638 m2/kg) instead of 0–45% cement by weight greatly grew the carbonation amount of concrete. The rise in carbonation may be due to the diluting and chemical results of LS, which may exhaust CH in the reflex ion between Limestone powder and the aluminate phase.

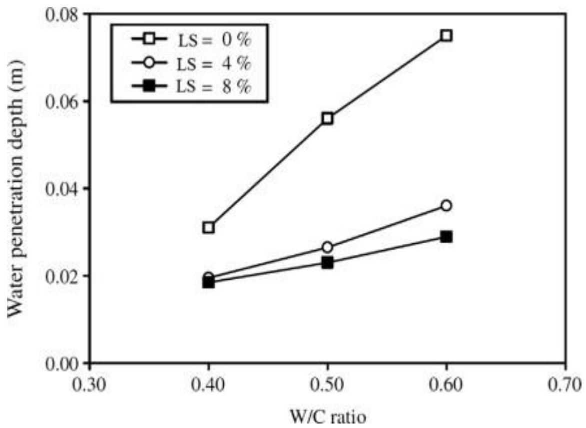

Fig. 4. Impacts of LS content on concrete's depth of water penetration [27].

Parrot [28] discovered that the depth of innate carbonation became more when more than 19% LS was used in place of cement. Nevertheless, the degree of carbonation of the weather in the concrete was somewhat lower when the limestone powder content was less than 15%. In contrast to concrete including fly ash or silica fume, the concrete including LS had a deeper carbonation depth. One reason could be the increased porosity of the concrete that contains LS [29].

7. Results and Discussion

According to several early experiments, the results of particle volume, content, alteration sample, and behavior technique of LS on the characteristic Various materials made of cement can be summed up as. According to the literature mentioned above, if appropriate fine limestone powder was added to Materials based on cement, it would primarily exhibit a nucleation impact and raise the cement's degree of hydration, resulting in the formation of additional C- S-H and CH at early ages. Nevertheless, the hydration products at a later age were not significantly impacted by the nucleation effect of limestone powder. The reaction between limestone powder and alumina in cement-based materials, which produces carbon aluminate, is the primary source of limestone powder's chemical impact on the hydration products of cement-based materials. Early on, when fine limestone powder was added, more carbo aluminate would occur; however, at later ages, the amount of carbo aluminate is the same regardless of the size of the limestone powder particles. If more limestone powder was added or SCMs containing $Al2O3$ were added, more carboalumination would develop. Thus, it can be concluded from the literature above that adding LS instead of fine aggregates or cement paste could boost compressive strength. However, when finer LS is added to replace cement, there is an ideal LS content for compressive strength; when the amount of LS is less than the perfect content, finer Limestone powder primarily exhibits a filler effect, and when the amount of LS exceeds the ideal content, finer LS primarily exhibits a dilution effect. There are complex effects of LS on concrete's flexural strength, elastic modulus, and compressive strength. Concrete's mechanical qualities are often improved when LS is added in place of cement paste or fine particles. The impact of LS on mechanical qualities, when it is used in place of cement, depends on the particle size and composition. Concrete's mechanical qualities will increase when a small amount of fine LS is used in place of cement; conversely, when a significant amount of coarse LS is used in place of cement, the concrete's mechanical qualities will drop. Permeability and sulfate resistance are the primary areas of study for how Limestone powder affects concrete durability. Concrete's impermeability is generally increased when Limestone powder is added in place of cement paste or fine particles. However, the effects of limestone powder on concrete's permeability when it is added in place of cement vary depending on the LS's particle size and composition. Concrete's ability to withstand sulfates would be negatively impacted by high LS and C3A contents.

8. Conclusion

Concrete characteristics are impacted by dilution, filling, and chemical reactions when mill dust is substituted for cement. When the replacement ratio is higher than ideal, dilution can weaken mechanical strength by reducing the amount of clinker and hydration products. In contrast, when fine dust particles are utilized, the filling effect increases concrete density and decreases porosity, improving durability and compressive. enhanced chemical reactions between cement dust and alumina produce carbolines, which in the early stages strengthen the material's structure. At later ages, these impacts, however, diminish. While high ratios may lead to decreased resistance to carbonation and sulfation, fine mill dust can also decrease water permeability and boost resistance to self-shrinkage. Although the effects vary depending on the size, ratio, and cement composition, using mill dust in measured amounts can often improve various mechanical qualities and durability. To get the most out of adding mill dust to concrete, it is advised to calculate the ideal ratio depending on building specifications.

9. Recommendations

Limestone powder has complex effects on cement-based materials' characteristics, typically exhibiting a mix of chemical, dilution, nucleation, and filling effects. The following is how LS should be used: It is advised to substitute LS for cement paste since doing so enhances the qualities of cement-based goods. It is advised to choose LS with a particle smaller than cement and content within a suitable range if LS is to be used in place of cement.

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