Modeling the Influence of Limestone Filler on Concrete: A Novel Approach for Strength and Cost

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ABSTRACT

The use of limestone fillers as additions in concrete has grown because they present several advantages over ordinary cements. Production of composite cements has caused a necessary shift in the manufacture process used in the cement industry. Now, it is known that the separate grinding and mixing technology is more convenient in order to produce these cements, called market-oriented or tailor-made cements. However, their optimum formulations require the help of methods of experimental design.

In this study, the incorporation of limestone fines and their optimal is analyzed in concrete, where Portland cement was replaced by up to 42 %. The fillers were chosen to be of various particle sizes. The resulting concretes are compared for compressive strength, cement consumption and economic viability. The results obtained indicate the advantage of incorporation of limestone fines in the concretes, as for the same compressive strength at 28 days, savings up to 23% in the consumption of cement were achieved, which represents a significant reduction of energy, raw material consumption and costs. The XRD analyses of samples cured up to 28 days showed that this amelioration is due to formation of new hydrated compounds. It is concluded that an addition of finely ground limestone filler up to 18% gives a better strength for the same cement content and reduces the cost of concrete for the same target strength.

KEYWORDS: Limestone filler, Concrete, Fineness, Modeling, Compressive strength, XRD.

INTRODUCTION

After many years of discussion, the ASTM C150 (2004); the standard specification for Portland cement, was modified to allow the incorporation of up to a 5 % mass fraction of limestone in ordinary Portland cements. Hawkins et al (2003) conducted an extensive survey of literature and concluded that the use of up to 5 % limestone does not affect the performance of Portland cement. Bonavetti et al. (2003) and Bents (2005) have reached a conclusion that even higher contents of ground limestone could potentially be utilized in lower water-to-cement ratios less than 0.45, where a substantial fraction of the cement clinker particles remains un-hydrated, effectively acting as a rather expensive filler material. Guemmadi and Resheidat et al. (2008) proposed optimal criteria of Algerian blended cement using limestone fines. They reached a definite conclusion that an inclusion of 15% of limestone fines is an optimal value that could be used in cement pastes. Because concretes made with

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limestone-containing cements are often prepared at a water-to-solids ratio similar to the water-to-cement ratio of the concrete with no limestone, the effective water-to-cement ratio of the limestone-filled concrete can substantially be increased from that of the original mixture. This will naturally modify the hydration characteristics of the concrete. Further, the additional surface area provided by the limestone particles may provide sites for the nucleation and growth of hydration products, generally enhancing the achieved hydration. Finally, the ground limestone is slightly reactive with the Portland cement, mainly forming a mono carboaluminate phase as pointed out by Klemm and Adams (1991) and by Kuzel and Pollman (1991).

Bentz (2006) suggested that prediction of the influence of a specific limestone substitution on the hydration behavior of a specific cement paste or concrete should expedite the usage of these filled cements and allow for a priori design of concrete mixtures that meet desired performance criteria. However, he suggested that his hydration model will be extended to consider the above influences of limestone fillers on cement hydration and to be validated against experimental measurements.

On the other hand and in response to economic development aiming at using natural resources, countries like Algeria and Jordan have been pursuing policies that aimed at optimizing the use of local materials. Algeria-for example- is boasting an ambitious program for housing and infrastructure facilities. The program includes the construction of one million housing units, 1200 km of motorways, three new cities around Algiers and other basic infrastructure such as schools, universities and hospitals. This program has raised challenges to the construction industry among which is the availability of good quality construction materials, especially those for concrete production. In both countries, crushed limestone remains the main source of aggregates used in concrete. However, such production is associated with high percentages of fines that make these aggregates unacceptable in the concrete design mix. As a result, over 20% of such products could not be used because they contain high amount of fines.

From a chemical point of view, Guemmadi et al. (2008) and Voglis et al. (2005) indicated that limestone fine does not have pozzolanic properties, but it reacts with the alumina pastes of cement to form a calcium mono-carboaluminate hydrate phase with significant changes in the strength of concrete. The focal point is that any research study considering to show the influence of admixtures on the properties of the cementing materials in connection with their smoothness and their more or less significant reactivity with cement can generate a significant change in the rheological and mechanical properties. The mechanisms at the origin of these modifications appear particularly complex, but several studies in this field agree to distinguish three principal effects which are superimposed to influence the properties of the cementing materials:

- ✓ The granular effect relating to all the modification induced by the presence of the fine or ultra fine particles in the fresh cementing materials in presence of water and possibly additives.
- ✓ The chemical effect concerning the capacity of the admixtures to react with water and the anhydrous or hydrated components of cement for forming new mineral pastes, which contribute to the mechanical strengths as well as the hydrated products of cement.
- ✓ The micro-structure effect: Guemmadi and Houari (2002) showed that the limestone admixture, the calcite ($CaCO_3$) reacts with aluminates of cement (C_3A, C_4AH_{13}) in the presence of water to form a hydrated mono carboaluminate of calcium of the type $C_3A.CaCO_3.11H_2O$, crystallized in fine hexagonal plates.

SIGNIFICANCE OF RESEARCH

This field of research is not a new one; but this scientific research and practical investigation tackle a problem where the percentage ratios of filler go beyond the code limits and shed light on a possible increase in such percentage ratios. The incorporation of limestone fillers in the concrete mix is not new and, for many years, the optimal amount of limestone in blended cement was discussed. Many of construction codes limit this amount to 5-10% by weight; accordingly, these codes need to be revised. It is important to know how these limestone fillers react with other cement compounds and with the other additions of cement, mortar and concrete. It is important to know the amount as well as the fineness of fillers that give better performances. For these reasons, the amount and fineness of limestone fillers have been varied in the concrete mix proportions. The test results of the concrete strength were accordingly recorded.

There were two main goals of this study. The first was to develop a relationship to predict the compressive strength of concrete containing limestone fines as cement substitution. This relationship may also have use in the field, reducing the need for laboratory testing. The second goal was to propose a new mix design for concrete with filler admixture. To evaluate the chemical contribution of the admixture to the flexible activity of cement, it is possible to determine the coefficient of reactivity of the admixture by applying the concept of the equivalent binder and by using analytical predictive model for the calculation of the compressive strength of the concrete and to analyze its variations according to the rate of the cement substitution. In this connection, we point to that the European standard EN 206-1 defines a standard coefficient of reactivity K of a certain admixture like the limestone in concretes. In addition, the French standard NF P 18-305 makes it possible to extend the applicability of the coefficient of reactivity K to certain additions of type 1 considered as quasi inert according to the standard EN 206-1.

The objective in designing concrete mixtures is to determine the most economic and practical combination of available materials to produce a concrete that will satisfy the performance requirements under particular conditions of use. The proportioning method is to determine an adequate and economic rate for the materials making up the concrete, which can be used in its production, giving as close as possible the desired properties, with the lowest cost. Cyr (2000) and Lawrence et al. (2003) outlined Dreux method as well as Aitkin method for proportioning concrete mixes adapted in this study. This choice has been made following some efficiency criteria, fundamental principles and technical limitations of each method. To accomplish this objective, a properly proportioned concrete mix will possess these qualities. It should be mentioned that there are several methods in designing a concrete mixture. Weight proportioning methods are fairly simple and quick for estimating mix proportions by an assumed or known weight of the concrete per unit volume. A more accurate estimate involves the use of the specific gravity value for all the ingredients to calculate the absolute volume each of them will occupy in a unit volume of concrete. Any one of the methods of proportioning concrete ingredients will produce approximately the same final mix.

ANALYTICAL MODEL

Dvorkin and Dvorkin (2006) described in their book the fundamental works of Feret, Abrams, Bolomey and other researchers who determined wide applications in practical technology of the water-cement (W/C) law (rule) and based on it computation formulae. After processing the results of more than 50 thousand tests, Abrams offered a formula:

$$R = \frac{k}{A^x} \tag{1}$$

where R is the strength of concrete; k is the strength coefficient, A is a constant value and x is the ratio between volume of water and volume of cement.

Graf offered at the end of the 20th years of the past century the formula of concrete strength (specifying the Abrams formula for practical calculations) as follows:

$$R = \frac{R_c}{A(W/C)^n} \tag{2}$$

where R_c is the compressive strength of Portland cement; A and n are coefficients (from Graf A=4..8, n=2); W/C is the water-cement ratio.

Bolomey (based on Feret dependence) determined a formula:

$$R = K\,(C/W - 0.5) \tag{3}$$

where R is the strength of concrete and K is a coefficient.

After the treatment of experimental researches, Skramtaev and Bagenov offered the formulae of concrete strength:

If $C/W \geq 2.5$ $\quad R = A\, R_c\, (C/W - 0.5)$ (4)

If $C/W \leq 2.5$ $\quad R = A_1\, R_c\, (C/W + 0.5)$ (5)

where, C/W is the cement-water ratio; A and A_1 are coefficients.

However, Eqn. (4) could be presented as follows:

$$R_{c28} = G.R_c \left(\frac{C}{W + V} - 0.5 \right) \quad (6)$$

where,

R_{c28}: Compressive strength of concrete at the age of 28 days, MPa.

C: Cement content, kg/m^3.

W: Water content, liter/m^3.

V: Voids in the concrete matrix.

G: A coefficient which depends on the nature of the aggregates.

R_c: Compressive strength of the normal cement mortar at the same age, MPa.

This expression may be simplified as:

$$R_{c28} = K \left(\frac{C}{W} - 0.5 \right) \quad (7)$$

Equation 7 is a particular case of Eqn. 6 in which $V = 0$ and $K = G\ R_C$. Involved parameters are: the cement content, C, the water content, W, and a coefficient K which takes into account the strength of cement mortar and the quality of aggregates.

In the application of Eqn. 7, the cement content was replaced by the equivalent binder, L, which is equal to the weight of cement and the weight of added filler, F, i.e. $L = C + F$. Considering that the filler is a percentage ratio of the cement content, $\alpha(p)$, where p denotes the percentage of filler, then Eqn. 7 becomes:

$$R_{c28} = K\left(\frac{C(1+\alpha(p))}{W} - 0.5 \right). \quad (8)$$

The coefficient K will be determined from the resistance of the reference concrete (without added limestone fillers) while the values of $\alpha(p)$ are obtained from the resistance to compression of concrete containing an increasing percentage of fillers.

EXPERIMENTAL PROGRAM

Program Outline

The experimental study consists of two stages. In the first stage, the compressive strengths of the specimens prepared from the concrete mixtures were determined after 28 days of standard curing about 350 kg/m^3 of cement. The second stage measurements had the aim to reduce the cost of concrete through an addition of finely ground limestone filler up to 18% to give a better strength content 250, 300, 350, 400 and 450 kg/m^3 of binder. In the second stage, concrete mixes were similarly cast, but binder content (cement and filler) was in the amount of 250, 300, 350, 400 and 450 kg/m^3. Records of the addition of finely ground limestone filler up to 18% were documented and presented to show the influence of the filler on the concrete strength. Moreover, interpretation, discussion and analysis of results were conducted and shown.

The tested specimens for the whole experimental program were made of the concrete, but details are only given for the binder content of 350kg/m^3 as shown in Table (1). The mix proportions were designed to study all parameters involved; namely, the percentage of fines and the median diameter of fines. The reference mix was made without fines. The addition of fines was conducted with percentages ranging from 6 to 42%. The fines were designated by F5, F10 and F29, respectively with the fillers diameter of 5 µm, 10 µm and 29 µm. Water to binder ratio was 0.57.

Materials

Cement: The cement used is Algerian CPA-CEMI cement, (CEM I 42.5 R according to EN 197-1) (European Committee for Standardization, 2000). From the clinker chemical and mineralogical characteristics, the laser gradation analysis reveals a distribution of the various particle sizes of grains ranging between 1 and 100 μm. The mineralogical composition of Portland cement was specified by: C_3S = 61.3%; C_2S = 15.9%; C_3A = 8% and C_4AF = 9.6%. The XRD analysis is shown in Figure (1).

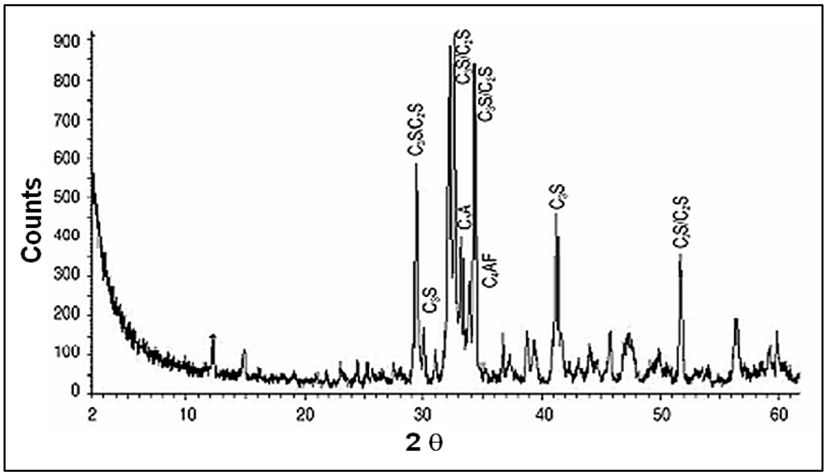


Figure (1): X-rays diffraction of anhydrous cement CEM I.

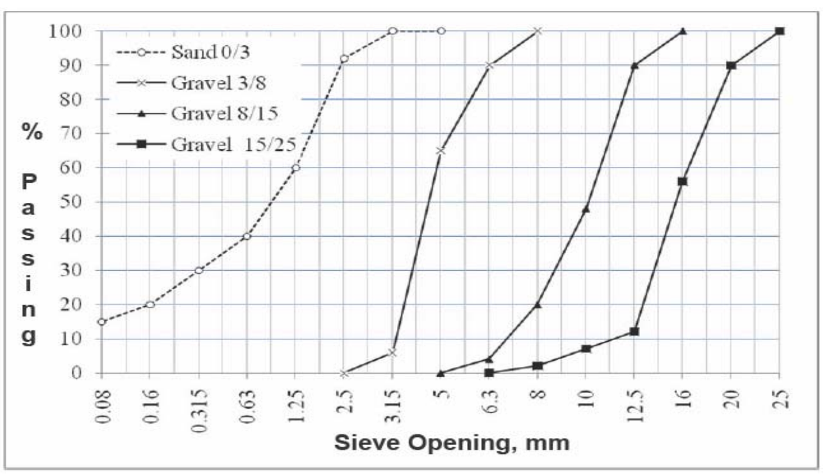


Figure (2): Aggregates gradation.

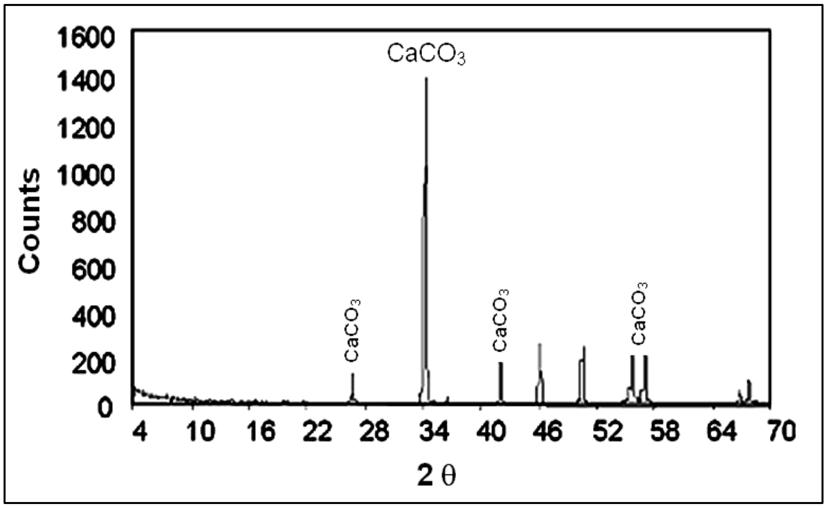


Figure (3): X-ray Diffractogram of filler.

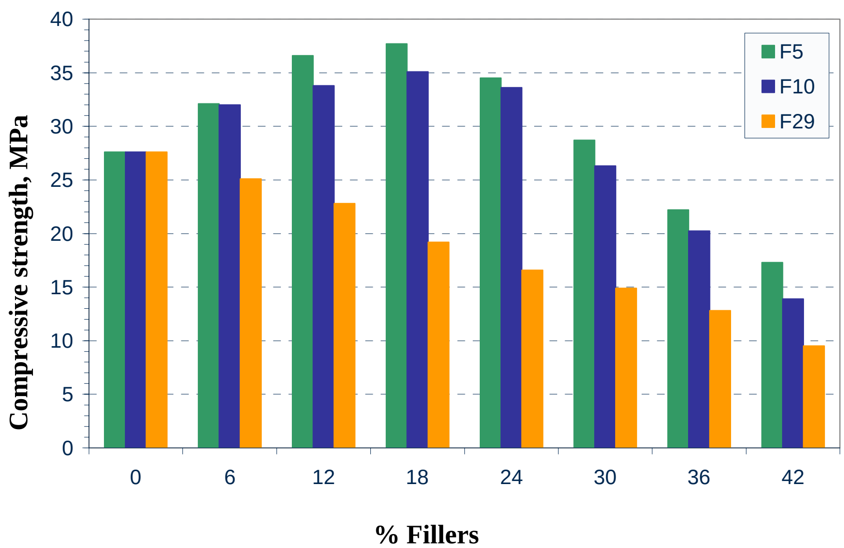


Figure (4): Influence of filler concentration on 28-day compressive strengths.

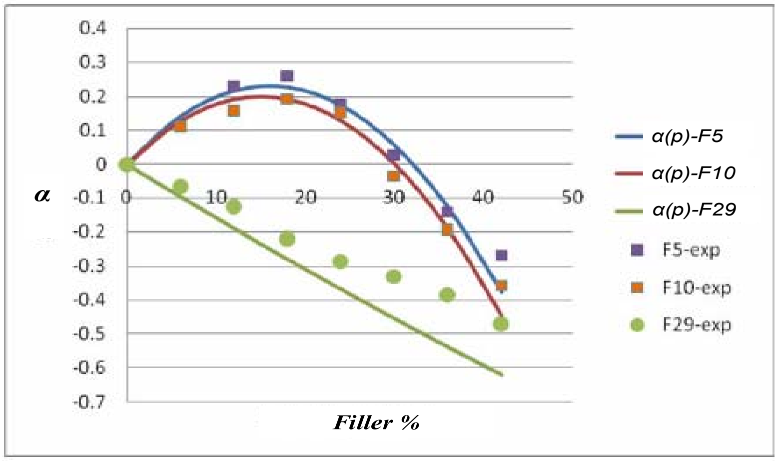


Figure (5): Evolution of *α* (*p*) versus percentage of fine.

Aggregates: The fine, medium and coarse aggregates were produced from calcareous crushed stone, commercialized under the names 0/3, 3/8, 8/15 and 15/25, used for the manufacturing of ordinary concrete in Algeria. The gradation of aggregates is shown in Figure (2).

Fillers: The fillers were limestone fines provided by a local company in the eastern part of the country. Their content of $CaCO_3$ is about 98%, the XRD analysis is shown in Figure (3). The fillers used are designated as F5, F15 and F29, where the subscript denotes the median diameter of the fines and their Blaine specific surface of 5400, 3500 and 2640 cm^2/g, respectively.

Portland cement (CEM I), limestone filler (F) and aggregates were used in this investigation. The chemical composition was obtained by X-rays fluorescence spectrometry, and the physical characteristics of these materials are shown in Tables (2 and 3).

Preparation of Specimens and Testing

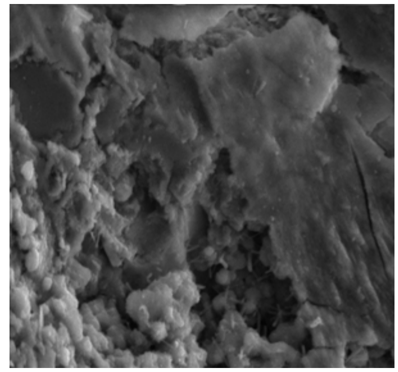
Twenty six concrete mixes were made for each type of cement used. Each mix was prepared to produce enough number of specimens that are needed to evaluate the compressive strength in addition to other tests that might be needed for SEM and XRD tests as well as for records beyond the age of 28 days. The slump was varied with the binder. The mix proportions and the properties of fresh concrete are shown in Table (1). Concrete specimens were cast in 160x320 mm cylindrical molds. The specimens were cast, covered with a plastic sheet and left in a laboratory environment for 24 hours. After demolding, cylinders were cured in water saturated with lime for 28 days. Compressive strength of concrete was determined by testing the 160x320 mm concrete cylinders. Records were based of the average of three results.

RESULTS AND DISCUSSION

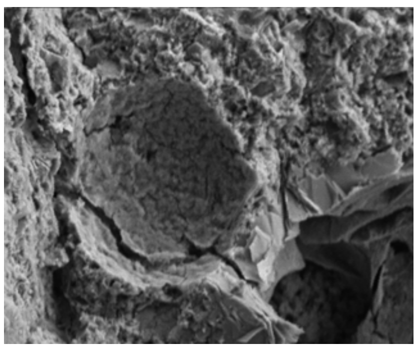
Influence of Limestone Filler Addition on Concrete Strength

The recorded test results given in Table (1) are presented in Figure (4). One can easily observe that the addition of filler F5 is the best one among the three types in improving the strength of concrete. The second one is the filler type F10. The third one which is F29 did not improve the strength of concrete; on the contrast it had a negative effect. The second observation is that the optimal value of addition of both F5 and F10 types was 18%. This indicates the possibility of reducing the cement content by 18%. The coefficient *K* will be determined from the resistance of the reference concrete (without added fillers, while the values of the *α (p)* are obtained from the resistance to compression of concrete containing an increasing percentage of fillers as shown in Figure (5).

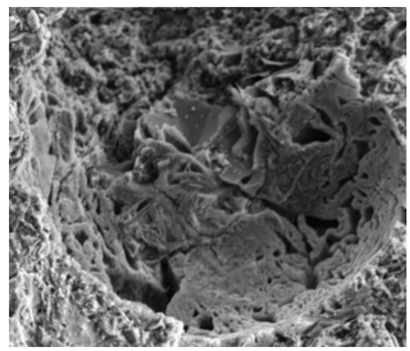
6.1: Formation of the carboaluminates crystals in concrete M18-F5 at 7 days.



6.2: Formation of CSH in concrete M18-F5 in 28 days.



6.3: Formation of pores at 28 days (M0).



6.4:.Formation of pores at 28 days (M40-F29).

Figure (6): Observation of blended concrete microstructure by SEM.

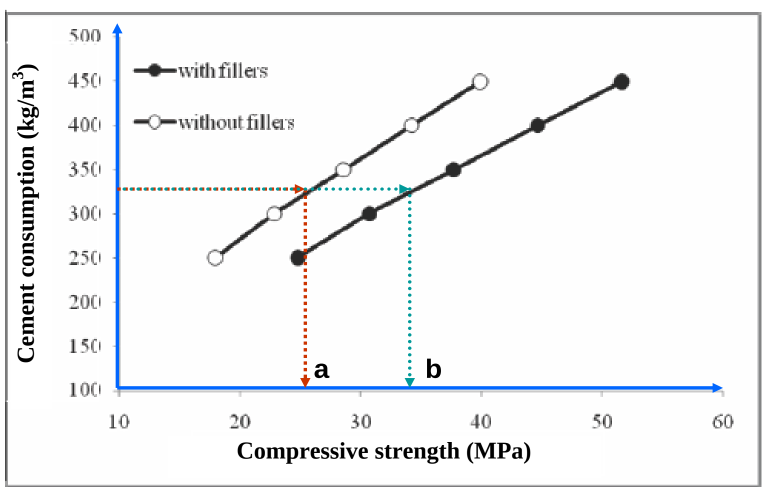


Figure (7): Cement consumption and strength.

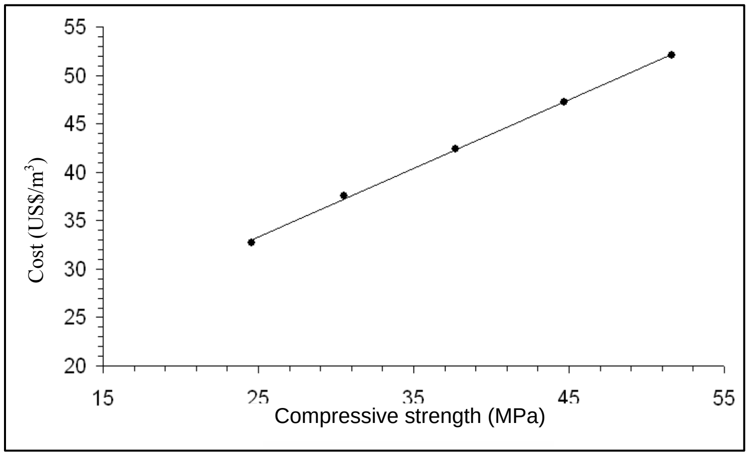


Figure (8): Cost of m^3 of concrete as function of strength.

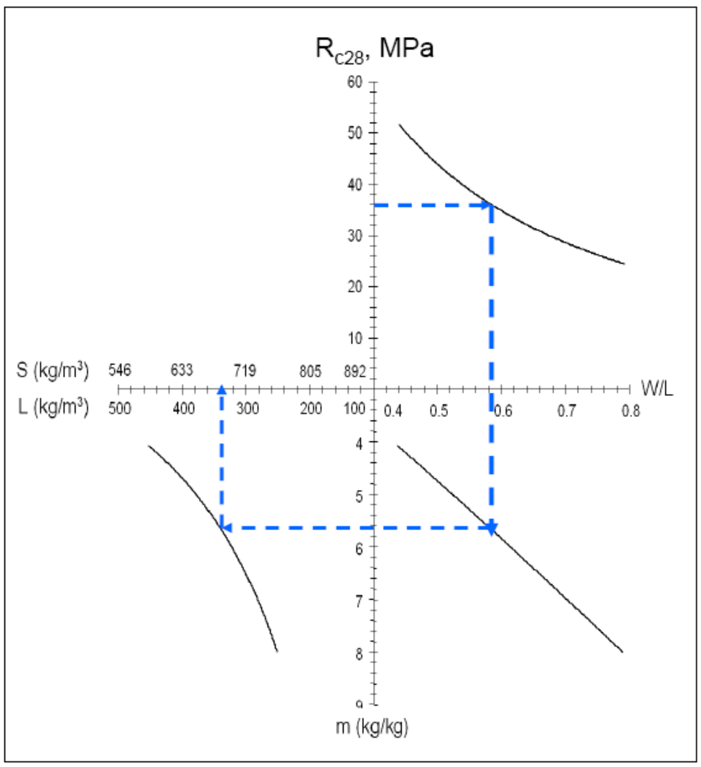


Figure (9): Mix proportioning diagram.

The influence of the filler addition on the microstructure of the hardened concrete was investigated by scanning electron microscopy. Figure (6) shows how filler F5 and F29 affect the microstructure of concrete incorporation. It is clearly shown that the M18-F5 addition gives the densest and most even structure to the concrete, which is as expected. The improvement of strength is essentially due to the acceleration effect of limestone filler related to the formation of calcium carboaluminates hydrate (Fig.6-1), which may be contributed to the overall increase in the rate of hydration. Also, the increased binding capacity of carboaluminates is likely due to its compact structure, Silica Calcium Hydrates (CSH) mapping of the specimens with M18-F5 showing how evenly the filler has been dispersed in the concrete (Fig. 6-2).

Table (1): Concrete mixture proportions, slump and compressive strength.

Mix*	Filler %	Proportions of mixes, kg/m³							Slump cm	R_{c28} MPa
		C kg	F kg	sand 0/3	Gravel 3/8	Gravel 8/15	Gravel 15/25	Water *litre*		
M0-F5	0	350	0	680	132	284	820	198	9.0	27.6
M6-F5	6	329	21	680	132	284	820	198	7.0	32.1
M12-F5	12	308	42	680	132	284	820	198	6.0	36.6
M18-F5	18	287	63	680	132	284	820	198	4.0	37.7
M24-F5	24	266	84	680	132	284	820	198	8.0	34.5
M30-F5	30	245	105	680	132	284	820	198	12.0	28.7
M36-F5	36	224	126	680	132	284	820	198	15.0	22.2
M42-F5	42	203	147	680	132	284	820	198	-	17.3
M6-F10	6	329	21	680	132	284	820	198	7.0	32.0
M12-F10	12	308	42	680	132	284	820	198	6.0	33.8
M18-F10	18	287	63	680	132	284	820	198	4.0	35.08
M24-F10	24	266	84	680	132	284	820	198	8.0	33.6
M30-F10	30	245	105	680	132	284	820	198	12.0	26.31
M36-F10	36	224	126	680	132	284	820	198	15.0	20.24
M42-F10	42	203	147	680	132	284	820	198	-	13.9
M6-F29	6	329	21	680	132	284	820	198	7.0	25.1
M12-F29	12	308	42	680	132	284	820	198	6.0	22.8
M18-F29	18	287	63	680	132	284	820	198	4.0	19.2
M24-F29	24	266	84	680	132	284	820	198	8.0	16.6
M30-F29	30	245	105	680	132	284	820	198	12.0	14.9
M36-F29	36	224	126	680	132	284	820	198	15.0	12.8
M42-F29	42	203	147	680	132	284	820	198	-	09.5
M18-F5-1	18	205	45	770	157	118	954	198	13.0	24.6
M18-F5-2	18	246	54	714	154	97	993	198	9.0	30.5
M18-F5-3	18	328	72	627	148	56	1045	198	10.0	44.7
M18-F5-4	18	369	81	595	126	72	1040	198	8.0	51.6

C: Cement content; F: Filler content; Slump reading ± 0.2 cm
* M 18-F5: Mix with 18% filler of the filler type F5.

Scanning electron microscopy confirms that the concrete becomes more heterogeneous when the amount of filler in concrete is very high, and also when the particle size of the added filler is increased. This phenomenon is due to the increase in pore sizes (Figs. 6-3 and 6-4).

To corroborate the results obtained in the concrete system, the evolution of α (p) function of incorporation fillers and its relationship with the compressive strength of concrete (W/L=0.57) were evaluated. The calculated values are presented in Table (4). Graphical representation is given in Figure (5). Concretes with fine limestone fillers exhibit strengths higher than those of the corresponding reference concretes at up to 18% of fillers. At 28 days, concretes with M18-F5 and M18-F10 binder developed an activity. The value of α (p) is approximately 0.23 for both concretes. This value is higher than the corresponding values obtained in the concrete system with filler F29. This is due to the heterogeneity of the concrete (increase of voids by air and interfaces), (Figures 6-3 and 6-4), but it can also be attributed to the accuracy of the method used. The coarse particles F29 have bad effect on performance. This phenomenon depends on the fineness and on the quantity of the admixture used.

Analysis of Filler Effect on Compressive Strength and Concrete Microstructure

The results of the compressive strengths of the different concretes are plotted in Figure (4). Generally, as the amount of limestone increases, the concrete containing limestone filler gives a higher strength than those of the cement especially with finely ground limestone F5. This behavior increases with the amount of limestone filler up to 18%. The incorporation of fines having a high specific area such as the finely ground limestone F5 and F10 considerably improves the compressive strengths, especially for values of substitution of around 18%. Beyond this value, the resistance decreases by about 75%. Concerning the coarse filler, F29, the compressive strength decreases for all amounts of substitution, which is essentially due to the formation of several families of pores as observed by SEM (Fig.6). The improvement of strength is essentially due to the acceleration effect of limestone filler related to the formation of calcium carboaluminate hydrates, which may be contributed to the overall increase in the rate of hydration. Also, the increased binding capacity of carboaluminate is likely due to its compact structure as described by Bonavetti et al. (2001). Furthermore, the consumption of calcite in the formation of carboaluminate hydrates, the accelerating influence on the hydration of CA, the changes in the calcium aluminates hydrates between limestone filler and the cement constituents, in addition to the fineness of limestone are the different factors specific to the reactivity of limestone filler. Numerous researchers have noted an acceleration of the hydration of cement due to the addition of limestone or other particles, and this is in agreement with the work of Kakali et al. (2000). Apparently, the surfaces of the individual filler particles provide sites for the nucleation cement hydration products such as the calcium silicate hydrate gel (CSH) which is the dominant hydration product in most hydrated Portland cements.

Table (2): Chemical composition of materials.

Chemical analysis				
Basic Oxide	Cement	Fillers	Aggregates	
			Fine	Coarse
CaO	64.01	55.85	55.80	55.80
SiO_2	20.01	0.58	0.06	0.06
Al_2O_3	4.65	0.06	0.04	0.04
Fe_2O_3	2.97	0.02	0.06	0.06
MgO	0.62	0.06	0.27	0.27
Na_2O	0.24	0.31	0.35	0.35
K_2O	0.02	0.25	0.01	0.01
SO_3	2.15	0.07		
LOI, % *Loss of Ignition*	4.34	43.58	42	42

Table (3): Physical characteristics of materials.

Material		Specific gravity	Blaine Specific Surface, cm^2/g
Cement		3.20	3500
Fillers	F5	2.70	5400
	F10	2.70	4500
	F29	2.70	2650
Aggregates	0/3	2.65	
	3/8	2.57	
	8/15	2.58	
	15/25	2.60	

Table (4): Determination of α *(p)* values.

p, %	0	6	12	18	24	30	36	42
L, kg	350	350	350	350	350	350	350	350
W, liter	198	198	198	198	198	198	198	198
W/*L*	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
R_{C28}-*F5*	27.6	32.1	36.6	37.7	34.5	28.7	22.2	17.3
R_{C28}-*F10*	27.6	32	33.8	35.1	33.6	26.3	20.2	13.9
R_{C28}-*F29*	27.6	25.1	22.8	19.2	16.6	14.9	12.8	9.5
α-F5	0	0.14	0.22	0.23	0.17	0.054	-0.13	-0.38
α-F10	0	0.13	0.20	0.19	0.13	0.001	-0.19	-0.45
α-F29	0	-0.10	-0.19	-0.28	-0.37	-0.46	-0.54	-0.62

Cement Consumption and Cost of Concrete

To determine the cement consumption per cubic meter of concrete, a regression analysis was performed on the compressive strength of concrete with 18% of F5. First, the water to binder ratio was linked to the compressive strength (Eqn. 9). Then the mass of total aggregates (sand and gravels) to binder ratio was linked to the water to binder ratio (Eqn. 10). Finally, the mass of binder 'L' was linked to 'm' (Eqn. 11). These fitting equations have a correlation of 0.999.

$$\frac{W}{L} = 9.7407\ f_{c28}^{-0.7849} \qquad (9)$$

$$m = 11.112\ \frac{W}{L} - 0.8058 \qquad (10)$$

$$L = 1545.7 m^{-0.8748} \qquad (11)$$

Starting from these equations, the cement (binder) consumption for a given strength was plotted in Figure (7). One could observe that for a given cement content (≈325 kg/m^3) where no fillers are added, the concrete strength is about 26 MPa; (point "a"). For the same content, the strength is about 33 MPa in case of adding fillers; (point "b"). As it may be shown, adding 18% of filler F5 reduces the cement consumption by about 23%.

To evaluate the cost of a cubic meter of concrete as a function of strength, a regression analysis was performed on the basis of the following values.

- Cement US$ 0.10/kg
- Filler limestone US$ 0.06/kg

- Fine aggregate US$ 7.22/m^3
- Coarse aggregate US$ 10.00/m^3

The best fitting relations for concrete made with pure cement and blended cement as a function of compressive strength are expressed by Eqns. (12 and 13), respectively as follows:

$$Cost = 0.7324R_{c28} + 7.3004 \quad (12)$$

$$Cost = 0.6757R_{c28} + 6.7403 \quad (13)$$

Figure (8) illustrates the cost per cubic meter of concrete, for the different strength ranges, although the lower cost for one cubic meter of concrete is obtained by adding 18% of F5 to the cement.

For rapid mixture design of concrete with 18% of F5, the masses of sand and gravel were also correlated to 'm' (Eqns. 14 and 15).

$$Sand = 254.51 \ln(m) + 240.94 \quad (14)$$

$$Gravel = mL - Sand \quad (15)$$

The mixture design diagram for this particular study could be used as shown in Figure (9).

SUMMARY AND CONCLUSIONS

The addition of fillers can affect concrete in three ways: on the physical, surface chemical, and the chemical levels. In this investigation, the physical and surface chemical effects can be seen in the results. The chemical effect, *i.e.,* Carboaluminates, can only be detected about SEM. The strengthening effect of filler on concrete paste is derived from the improvement of the pore structure. The number of small pores is increased at the same time as the number of large pores decreases, which has a positive influence on strength and durability. This study helped valorize local limestone fines, which may contain high calcareous filler proportions, up to 42% of the cement mass. For that purpose, the added filler to concrete had been formulated by substitution to cement, with constant ratio water to binder ratio taking into account the degree of fineness of the used fillers. The mechanical and micro-structural properties have been investigated simultaneously using varied experimental techniques. The absence of potentially harmful clayey constituents has been checked through SEM microscopic studies and led to demonstrate that concrete containing fine particles of 18%, exhibited a denser and more homogenous structure than concrete without filler. Test results also showed that the distribution of the filler in the concrete was very good, even around the aggregates, which proves that filler addition improves particle packing and reduces the wall effect. The homogeneity of the concrete containing the finest fillers may be a possible result of the particles acting as nucleation sites, thus improving the hydration. With a filler content of 18%, the mechanical performance of the concretes is clearly improved. The limestone filler acts primarily as an accelerator. It increases the rate of hydration and serves as crystallization nuclei. The rate of hydration increases with the content and fineness of filler in the concrete mix. The consumption of calcite, the formation of carboaluminates, the accelerating effect on the hydration of C_3A, C_3S, the change in the CSH and the formation of a transition zone between the filler and concrete, are all facts specific to the reactivity of limestone fillers which are mainly conditioned by the fineness.

The fineness of limestone fines plays a considerable role in the improvement of mechanical performances of the concrete due to the formation the new compounds such as carboaluminates.

The various results obtained show that it is beneficial to use limestone fillers. The following conclusions may be drawn from this study:

1. The chemical and physical roles of filler addition lie in the formation of carboaluminates, crystal nuclei are due to the degree of fineness and particle size of fillers.
2. The influence of the finest fillers is considered to be favorable when their content is lower than 30%.
3. The optimal filler content that allows the obtaining of highest resistance is 18%.
4. It is possible to produce concrete with a compressive strength of about 50 MPa.
5. Concerning the cost per cubic meter, it is well

known that the concrete having the less consumption of cement per m^3 of concrete is always the cheapest.

6. The use of fillers as presented is not only beneficial to the concrete industry, but also is friendly to the environment.

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