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A study on the parameters affecting the properties of Portland limestone cements

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Abstract

In this paper the parameters affecting the properties of Portland limestone cements are investigated. Portland limestone cements of different fineness and limestone content have been produced by intergrinding clinker, gypsum and limestone. Two kinds of clinker of different chemical composition, mineralogical composition and strength development and three limestones, with different contents of calcite, dolomite, quartz and clay, have been used. It is concluded that the appropriate choice of the clinker quality, limestone quality, % limestone content and cement fineness can lead to the production of a limestone cement with the desired properties. Limestone cements, having up to 10% limestone content and fineness up to a limit value, develop almost the same compressive strength, as the corresponding pure cements. The limestone cements, generally have lower paste water demand than the relative pure cements and the water demand decrease is mainly affected by the clinker type and limestone quality. In any case the properties of the limestone cements are affected by the interaction of the two components rather than their individual properties.

Keywords: Portland limestone cement; Clinker quality; Limestone quality; Limestone content; Cement fineness; Compressive strength; Physical properties.

1. Introduction

The use of Portland-composite cements, especially those containing limestone, seems to have many benefits, both technical and economical [1–5]. The European Standard prEN 197-1 (1996) identifies 2 types of Portland limestone cement containing 6–20% limestone (type II/A-L) and 21–35% limestone (type II/B-L) respectively [6,7].

According to the literature, the research work on limestone cement is focused on three areas. The first one is the effect of the limestone on the cement performance. The second one deals with the participation of the limestone in the hydration reactions of the clinker while the third one concerns the production process and specifically the co-grinding of clinker and limestone.

As far as the cement performance is concerned, there is a disagreement whether the fine limestone tends to reduce or enhance the strength development but it is generally accepted that there is a positive effect of limestone on the water demand [4,5,8–12].

As far as the clinker hydration is concerned, it is generally agreed that limestone participates in the hydration reactions rather than being an inert filler but there is considerable disagreement on the estimation of the limestone amount that is incorporated into a cement system [13–18].

As far as the cement preparation is concerned, the research work deals mainly with the particle size distribution of co-ground clinker and limestone [8,19,20].

It must be noted that, in most of the research work, the effect of limestone on the cement performance and hydration process is studied using pure clinker phases and $CaCO_3$ and in cements produced by blending OPC with ground limestone (not interground). Besides, there is a lack of information concerning limestone additions over 25%.

The review of the literature gives rise to several questions: What is the effect of clinker and limestone quality on the cement performance? How can the hydraulic potential of clinker be exploited in the best way? Is the interaction of the materials of greater importance than their individual properties?

The present work deals with the above questions, taking into account the growing use of limestone as a

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Table 1
Chemical and mineralogical composition of clinker

Chemical composition (%)			Mineralogical composition (%)		
	C1	C2		C1	C2
SiO_2	21.79	21.75	C_3S	65.15	57.99
Al_2O_3	5.13	5.74	C_2S	13.32	18.60
Fe_2O_3	3.59	2.06	C_3A	7.54	11.74
CaO	66.42	65.04	C_4AF	10.92	6.26
MgO	1.71	2.67	Moduli		
K_2O	0.55	1.24			
Na_2O	0.09	0.22	LSF	95.70	94.26
SO_3	0.52	1.08	SR	2.50	2.79
			AR	1.43	2.79
			HM	2.18	2.20

cement constituent. More specifically the effect of the clinker and limestone quality, the limestone content and the cement fineness on the mechanical and physical properties of Portland limestone cements are studied. This work is a part of a project, developed in our laboratories, concerning the properties of limestone cement and concrete.

2. Experimental

Two kinds of clinker (C1, C2) with different chemical and mineralogical composition (Table 1) as well as strength development have been used. Three limestones have been used. The first one (L1) has the higher content of calcite while the second and the third contain significant amounts of dolomite (L2) and quartz/clay (L3) respectively. All the limestones meet the requirements of the prEN 197-1 (Table 2).

The pure cements (clinker C1 or C2 plus 5% gypsum) were ground to four different predefined fineness as: 2800, 3100, 3400 and 3700 cm^2/g (3900 cm^2/g for C2). The required grinding time was 38, 45, 52, 60 min and 37, 44, 51, 66 min for clinker C1 and C2 respectively. 88 Portland limestone cements were produced by intergrinding of clinker, limestone and gypsum in a pro-pilot plant ball mill of 5 kg capacity. The cements were prepared by the combination of each clinker (C1, C2) with each limestone (L1, L2, L3, 5–35%) ground to four different fineness levels, applying the grinding times mentioned above. The codes of the samples are given in Table 3 while the specific surface of the samples is presented in Table 4.

Table 2
Chemical composition of limestones and chemical requirements of prEN 197-1

Chemical composition (%)				Chemical requirements			
	L1	L2	L3	Permitted constituents	L1	L2	L3
SiO_2	0.61	0.10	8.25	$CaCO_3 > 75\%$	95.3	88.4	84.1
Al_2O_3	0.15	0.16	1.52	MBA < 1.2 g/100 g	0.1	0.1	0.2
Fe_2O_3	0.17	0.02	0.62	TOC < 0.2%	—	—	—
CaO	53.36	49.51	47.09				
MgO	1.47	4.99	0.45				
K_2O	0.02	0.01	0.30				
Na_2O	0.00	0.02	0.06				
LOI	43.54	44.35	37.50				

Table 3
Codes of the samples

Portland limestone cement: *CiLj-c-t**
C = clinker
i = clinker quality (1,2)
L = limestone
j = limestone quality (1,2,3)
c = limestone (%)
t = grinding time (min)

*: The pure cements are referred as *Ci-t*.

The compressive strength of the samples (EN 196-1) as well as the consistency of standard paste, the setting time and the soundness (EN 196-3) were determined. In addition, the linear shrinkage/expansion of limestone cement mortars was measured (NF P 15-433).

3. Results and discussion

Table 4 presents the compressive strength of the tested samples, while Figs 1 and 2 show the influence of limestone content on the strength development of C1L1–c–45 and C2L1–c–44 respectively. It is observed that the addition of 10% limestone does not significantly alter the compressive strength at any age of samples C1L1, C1L2, C1L3, C2L1, C2L2, and C2L3 having fineness up to 3800, 3400, 4100, 4300, 3800 and 4300 cm^2/g respectively. Further increase of the cement fineness leads to the production of limestone cements having compressive strength lower than the pure ones. In general, the influence of the fineness on the compressive strength is stronger in the range of limestone addition from 5 to 10%. Comparing the two clinkers, it is observed that clinker C2 can 'cooperate' better with limestone than C1, even at high levels of fineness. As far as the limestone quality is concerned, it is concluded that L1 and L3 have more positive effect on the strength development than L2.

In Figs 3 and 4 the classification of the tested cements, according to the strength classes of prEN 197-1, is given. In these figures the drawn lines of each limestone represent the combinations of specific surface and limestone content that lead to cement compressive strength (28 days) equal to the lower limit value of strength classes (e.g. 42.5 N/mm^2 for class 42.5). It is concluded that the appropriate choice of the

Table 4
Mechanical and physical properties of the produced Portland limestone cements

Sample	Fineness		Compressive strength (N/mm^2)				Paste water dem. (%)	Setting time (min)		Exp. (mm)
	S_b (cm^2/g)	Residue at 32 μm (%)	1 d	2 d	7 d	28 d		Initial	Final	
PORTLAND CEMENTS C1										
C1–38	2830	29.0	11.4	20.6	36.1	50.2	26.0	160	215	
C1–45	3150		14.5	24.7	40.6	53.8				
C1–52	3390	21.2	16.6	28.6	42.2	57.2	25.7	130	190	
C1–60	3710	20.2	19.0	31.0	46.9	58.2	25.7	110	145	0.5
PORTLAND LIMESTONE CEMENTS C1L1										
C1L1–5–38	3040		11.8	22.7	38.9	52.3				
C1L1–5–45	3490		15.4	25.5	43.8	54.9				
C1L1–5–52	3780		16.5	27.8	45.5	54.8				
C1L1–5–60	4000		18.0	29.2	47.7	56.2				
C1L1–10–38	3320	26.4	11.4	20.8	39.1	49.5	25.4	145	190	
C1L1–10–45	3830	22.3	15.0	25.9	44.0	53.3	25.0	145	195	
C1L1–10–52	4060		14.5	24.6	41.3	54.1				
C1L1–10–60	4410	19.1	14.6	25.3	44.1	55.0	25.1	120	170	1.0
C1L1–15–38	3690		9.0	20.9	36.5	47.0				
C1L1–15–45	4190		13.2	23.5	42.2	49.5				
C1L1–15–52	4410		14.3	22.8	39.5	49.6				
C1L1–15–60	4770		14.9	28.1	43.4	52.7				
C1L1–20–38	3990	27.5	10.9	20.6	36.2	44.6	23.5	105	180	
C1L1–20–45	4330	24.5	11.0	21.4	37.6	45.9	23.2	110	180	
C1L1–20–52	4670		12.8	22.5	37.9	45.6				
C1L1–20–60	4830	23.1	13.2	24.0	39.0	46.6	23.4	115	185	0.5
C1L1–25–38	4350		9.2	19.4	34.4	41.9				
C1L1–25–45	4550		9.9	19.2	32.3	41.2				
C1L1–25–52	4900		11.1	20.2	34.5	41.0				
C1L1–25–60	5090		11.4	21.3	35.5	42.0				
C1L1–30–38	4560		9.6	18.4	32.5	40.6				
C1L1–30–45	4790		8.9	17.4	29.9	36.9				
C1L1–30–52	5290		9.5	18.1	30.6	38.2				
C1L1–30–60	5440		9.8	18.4	31.7	39.1				
C1L1–35–38	4790	26.6	7.8	15.4	27.6	34.3	22.9	105	165	
C1L1–35–45	5150	22.6	7.5	15.9	27.2	33.5	22.8	100	165	
C1L1–35–52	5430		8.6	15.8	26.4	35.2				
C1L1–35–60	5850	19.5	9.1	17.1	28.9	35.9	23.1	90	150	1.0
PORTLAND LIMESTONE CEMENTS C1L2										
C1L2–10–38	3370	24.4	11.3	21.0	38.3	49.1	24.9	135	185	
C1L2–10–45	3830	23.2	13.1	23.6	41.4	50.8	23.8	11	175	
C1L2–10–52	4130		14.7	24.5	41.6	52.4				
C1L2–10–60	4420	21.0	16.8	29.0	43.7	54.3	24.1	115	175	
C1L2–20–38	3910		10.6	20.2	34.3	43.6	23.0	135	185	
C1L2–20–45	4330		11.6	21.7	36.9	44.9				
C1L2–20–52	4560		11.1	23.0	37.3	47.0	23.0	130	185	
C1L2–20–60	4740	24.3	11.4	21.8	36.2	44.3	22.8	110	175	
C1L2–35–38	4700		7.2	14.4	26.3	33.1	23.1			
C1L2–35–45	5100		7.3	14.8	26.8	33.6	22.5			
C1L2–35–52	5250		7.6	14.9	26.5	33.0				
C1L2–35–60	5350	25.4	7.9	14.8	26.9	33.7	22.5	105	180	0.5
PORTLAND LIMESTONE CEMENTS C1L3										
C1L3–10–38	3610		12.7	23.9	39.3	52.5	25.0	145	190	
C1L3–10–45	4090		12.7	25.4	44.3	53.2	24.5	150	215	
C1L3–10–52	4360		16.4	28.0	47.7	55.8				
C1L3–10–60	4640	21.1	17.2	26.8	47.6	55.6	24.4	130	200	
C1L3–20–38	4310		10.9	21.8	38.5	47.3	24.1	150	210	
C1L3–20–45	4610		12.7	23.4	41.1	49.0	23.9	150	220	
C1L3–20–52	4860		14.2	25.4	42.3	49.6				
C1L3–20–60	5200	19.5	14.5	26.0	43.0	49.7	24.5	120	180	
C1L3–35–38	5020		8.4	17.2	30.4	36.5	23.9	135	210	
C1L3–35–45	5400		9.4	17.7	30.4	36.5				
C1L3–35–52	5550		9.5	17.9	31.0	37.6	24.3	125	175	
C1L3–35–60	5720	19.0	10.1	18.7	32.1	38.1	23.8	135	190	1.0
PORTLAND CEMENTS C2										
C2–37	2810		16.7	24.1	32.9	41.1	28.2	110	180	
C2–44	3110		18.4	26.2	34.5	42.7	29.2	135	190	
C2–51	3390		20.4	28.2	365	45.0	28.3	120	160	0.5
C2–66	3910	16.7	23.4	31.2	38.8	47.1	28.6			

Table 4
(Continued)

Sample	Fineness		Compressive strength (N/mm^2)				Paste water dem. (%)	Setting time (min)		Exp. (mm)
	S_b (cm^2/g)	Residue at 32 μm (%)	1 d	2 d	7 d	28 d		Initial	Final	
PORTLAND LIMESTONE CEMENTS C2L1										
C2L1–10–37	3360		16.7	26.1	35.2	43.4	28.7	110	180	
C2L1–10–44	3900		17.4	27.8	35.4	43.0				
C2L1–10–51	4130		18.8	29.4	37.0	44.3	28.9	130	180	
C2L1–10–66	4890	18.3	21.4	30.8	38.1	44.7	28.6	120	200	
C2L1–20–37	3910		14.2	22.6	30.4	37.3				
C2L1–20–44	4340		15.5	24.6	32.5	39.4				
C2L1–20–51	4750		16.2	26.3	33.9	39.9				
C2L1–20–66	5190	19.1	17.0	26.7	33.3	40.0	28.4	130	200	
C2L1–35–37	4790		9.2	16.3	23.7	29.0				
C2L1–35–44	5080		9.4	16.8	24.0	29.3				
C2L1–35–51	5460		10.5	18.4	25.3	31.0				
C2L1–35–66	5780	20.2	10.8	18.6	25.2	29.8	28.3	120	180	0.5
PORTLAND LIMESTONE CEMENTS C2L2										
C2L2–10–37	3380		15.6	25.7	32.6	41.1				
C2L2–10–44	3780		16.9	27.2	33.5	41.6				
C2L2–10–51	4290		18.0	28.2	35.7	42.3				
C2L2–10–66	4830	18.3	22.7	28.6	33.8	42.2	28.1	110	180	
C2L2–20–37	3940		13.4	22.2	29.7	35.9				
C2L2–20–44	4320		14.5	23.7	30.3	37.9				
C2L2–20–51	4670		17.8	24.6	29.2	35.0				
C2L2–20–66	5400	16.1	16.9	24.0	30.0	36.3	27.8			
C2L2–35–37	4680		7.8	14.1	20.0	25.8				
C2L2–35–44	5090		9.4	16.5	23.1	26.8				
C2L2–35–51	5360		12.2	17.5	22.3	26.4				
C2L2–35–66	5900	17.5	14.2	20.9	25.9	27.8	27.6	100	170	1.0
PORTLAND LIMESTONE CEMENTS C2L3										
C2L3–10–37	3440		16.9	26.4	34.1	41.1				
C2L3–10–44	3940		17.5	28.3	35.5	42.8				
C2L3–10–51	4310		18.9	29.6	36.7	44.4				
C2L3–10–66	4830	15.0	23.0	31.9	37.8	45.2	28.4	95	160	
C2L3–20–37	4150		14.6	23.3	31.2	37.1				
C2L3–20–44	4740		14.8	24.6	32.0	37.6				
C2L3–20–51	4980		17.7	27.8	34.4	40.1				
C2L3–20–66	5680	14.8	19.7	28.8	34.1	40.1	29.1	80	160	
C2L3–35–37	5010		10.7	18.1	24.7	29.5				
C2L3–35–44	5610		11.4	19.3	26.3	30.4				
C2L3–35–51	6010		12.5	20.3	26.0	31.7				
C2L3–35–66	6670	18.1	14.3	22.2	27.3	32.5	28.4	110	160	1.5

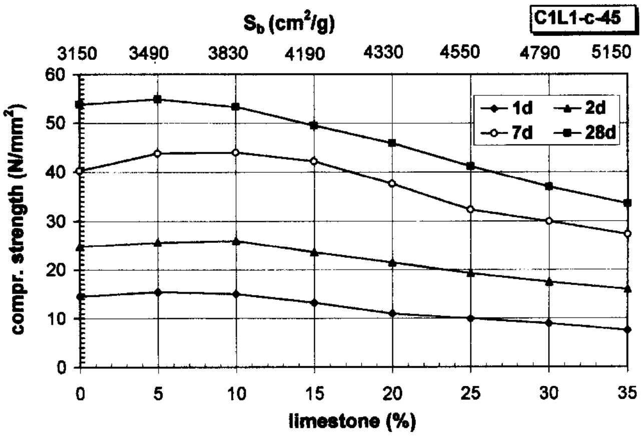

Fig. 1. Influence of limestone content on strength development of C1L1 (grinding time: 45 min).

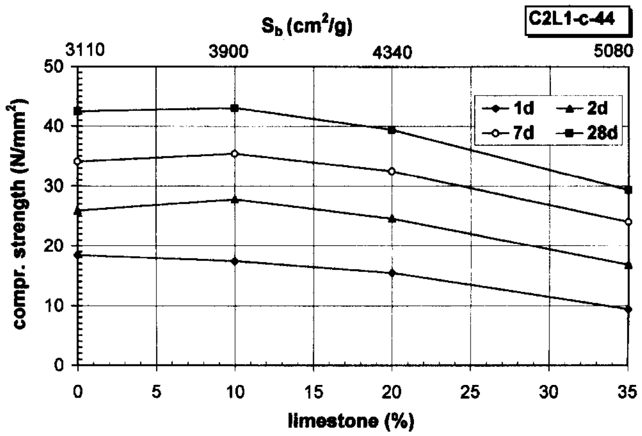

Fig. 2. Influence of limestone content on strength development of C1L2 (grinding time: 44 min).

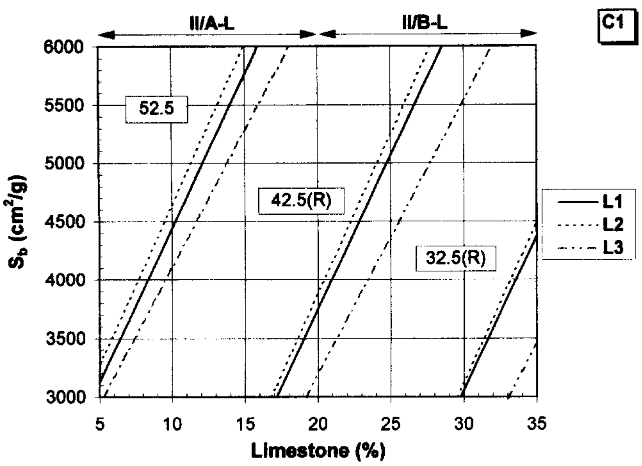

Fig. 3. Classification of the cements containing clinker C1 according the strength classes of prEN 197-1 (The area between the drawn lines of each limestone represents the combinations of S_b and limestone content that meet the requirements of the mentioned strength class.)

clinker quality, limestone quality and cement fineness can lead to a cement production of desired properties. From both figures it is also observed that the dolomitic limestone (L2), compared with L1 and L3, seems to have the lower contribution to strength, particularly for the clinker C2.

In order to indicate more clearly the contribution of the limestone to the cement mechanical properties the 'interaction factor' (I.F.) has been introduced. It is derived from the relation I.F. $= (S_1 \times 100)/(S_0 \times Cl)$ where $S_1 = 28$ d compressive strength of Portland limestone cement, Cl = clinker content of the above cement and $S_0 = 28$ d compressive strength of the pure cement ground for the same time. I.F. presents the ratio of the limestone cement strength (expressed on

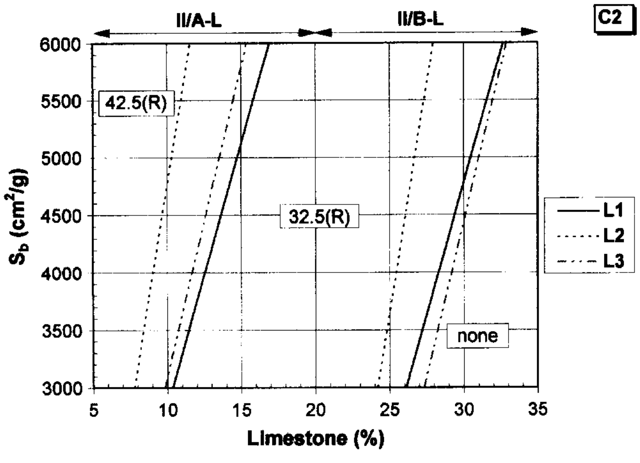

Fig. 4. Classification of the cements containing clinker C2 according the strength classes of prEN 197-1 (The area between the drawn lines of each limestone represents the combinations of S_b and limestone content that meet the requirements of the mentioned strength class.)

the basis of 'clinker' content instead of 'clinker+limestone' content) to the pure cement strength. In fact I.F. indicates the effect of limestone addition on the hydration process of the clinker. I.F. values greater than 1, indicate that the limestone addition favors the hydration and improves the strength development of the clinker.

The values of I.F. are given in Figs 5 and 6 concerning the cements C1Lj and C2Lj respectively. As it is shown there is an important effect of the limestone and clinker quality as well as of the cement fineness on the reactivity and the strength development of the clinker. As it is observed clinker C2 takes greater advantage from the limestone presence than clinker C1. This can be associated with the higher content of C_3A, which reacts with $CaCO_3$ forming carboaluminates. In addition, the dilution of alkalis (higher content in C2) with limestone, lowers the alkali concentration in the pore solution and permits more effective clinker hydration. It is also observed, that limestone L3 has the greater contribution to the strength development. The limestone L3 improves the reactivity and strength development of the clinker in all the studied cements. The limestone L1 has a similar effect to L3 on the strength development only with clinker C2. When it is mixed with clinker C1, L1 favours the clinker hydration and strength development for contents up to 20%. For higher percentages its positive (I.F. > 1) or negative (I.F. < 1) contribution is dependent on the cement fineness. The limestone L2 has a similar effect with L1, as far as clinker C1 is concerned. When it is mixed with C2 it favours the clinker hydration and strength development for contents up to 10%. For higher percentages its positive (I.F. > 1) or negative (I.F. < 1) contribution is strongly related to the cement fineness. In any way the L3 addition, in percentages greater than 30%, is not advised.

Table 4 presents the cement paste water demand, the setting time and the expansion of the tested samples. The term 'water demand' is generally considered to be the quantity of water which is required in order to prepare a cement paste of standard consistency as specified in EN 196-3. The limestone cements, despite their higher fineness, generally demand less water than the relative pure cements. In limestone cements based on clinker C1, and containing 10% limestone, there is a reduction of water demand from 26% to 24%–25%. The increase of the limestone content to 20% and 35% causes a decrease of the water demand to 24%–22.5% (Fig. 7). The limestones L1 and L2 affect the water demand more than limestone L3. In limestone cements based on clinker C2 there is no significant effect of the content and quality of limestone on the water demand which is almost similar to that of the pure cement. However in

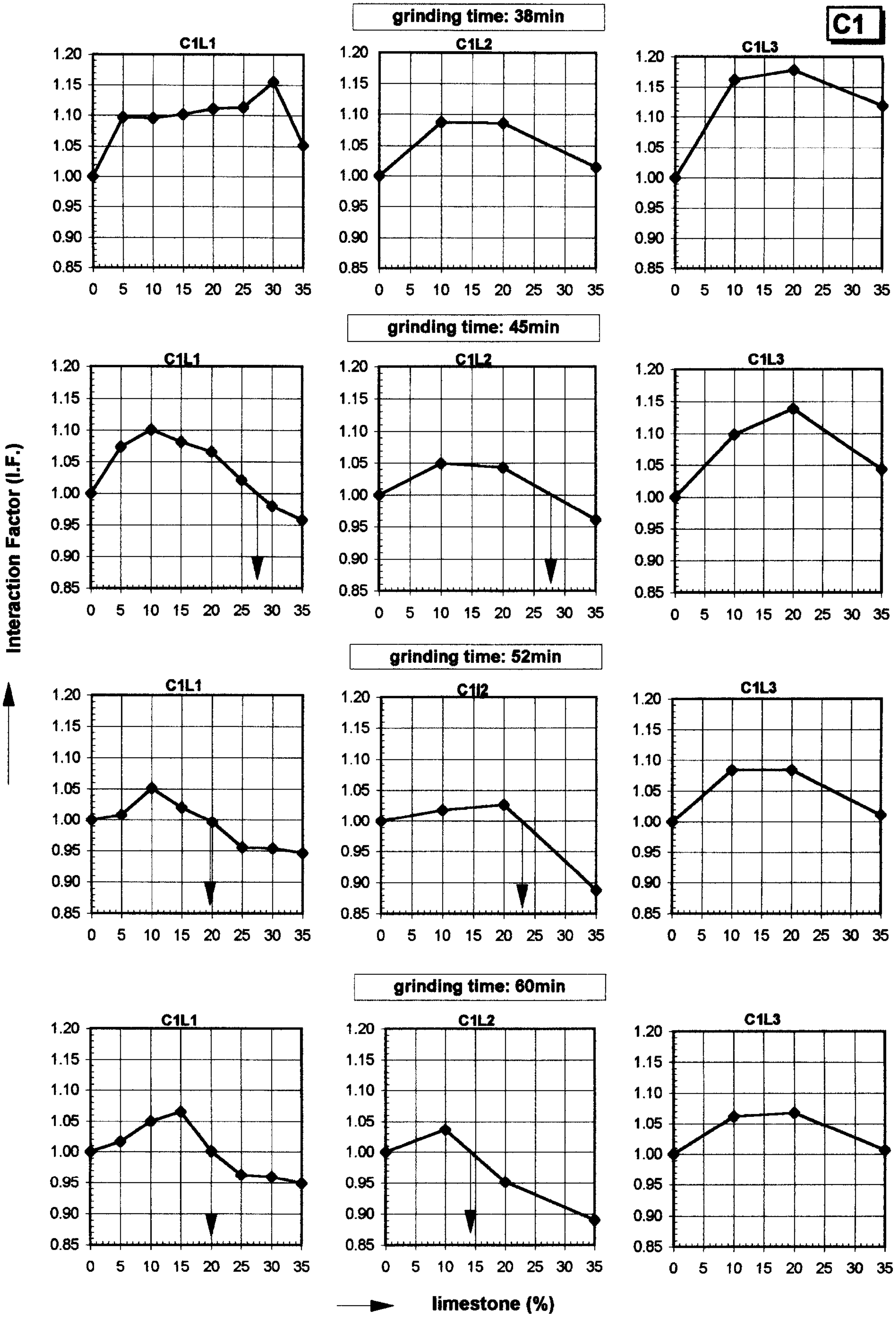

Fig. 5. Effect of the grinding time, the limestone quality and the limestone content on the I.F. for cements containing clinker C1.

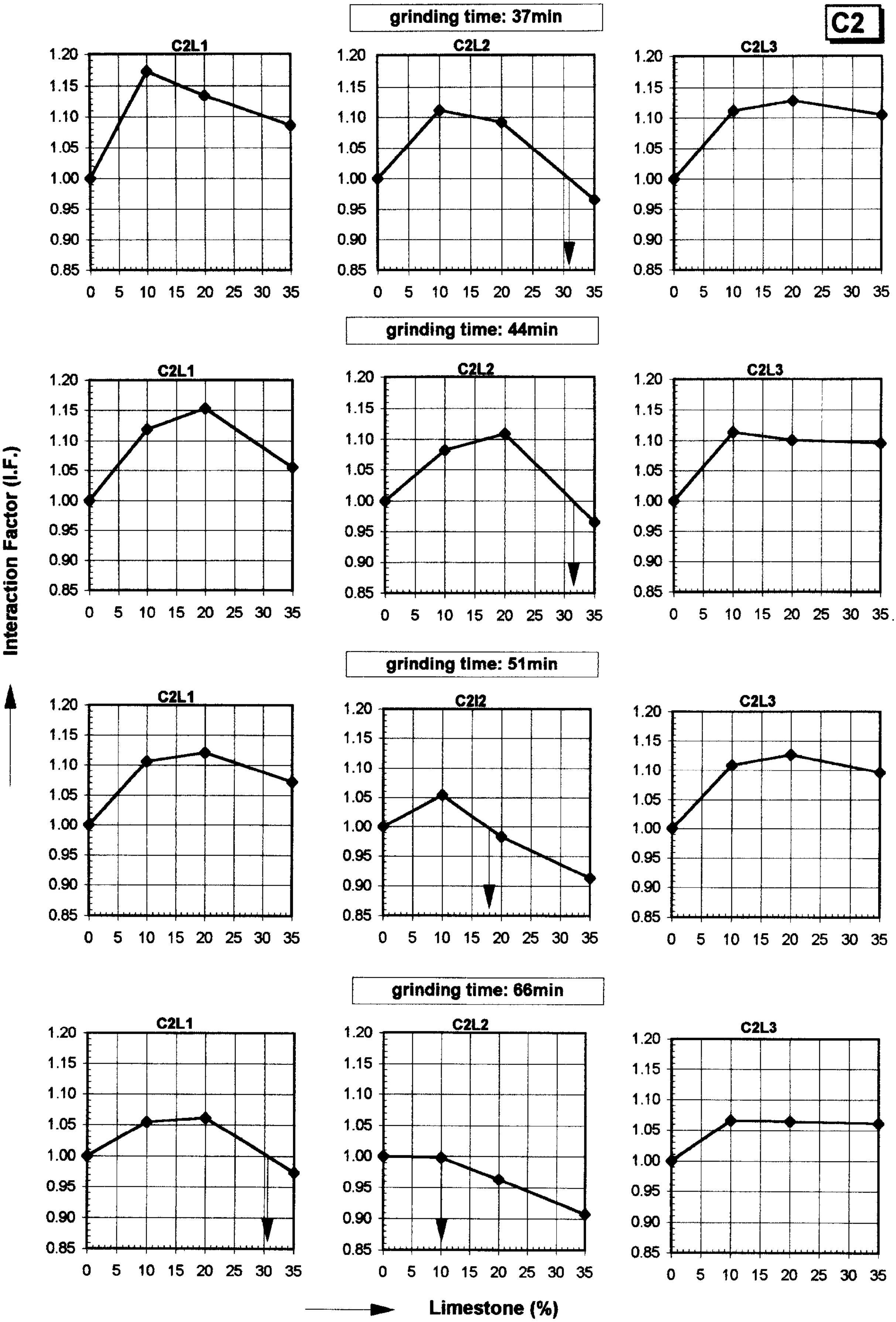

Fig. 6. Effect of the grinding time, the limestone quality and the limestone content on the I. F. for cements containing clinker C2.

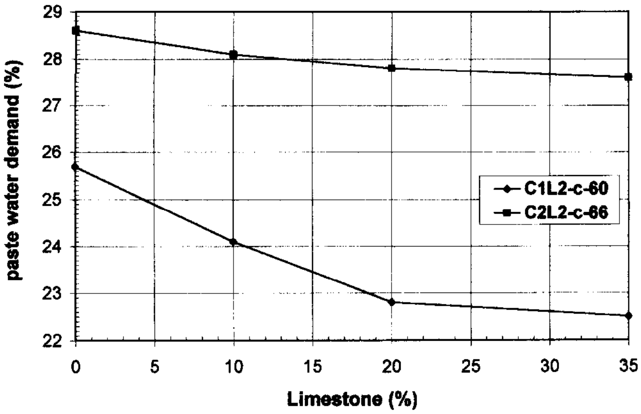

Fig. 7. Paste water demand of cements C1L2-c-60 and C2L2-c-66 in relation to the limestone content.

cements containing L2 there is reduction of water demand up to 1% (Fig. 7).

The effect of limestone on the paste water demand of cements can be attributed to the different particle size distribution of the samples. Limestone cements despite their higher fineness have wider particle size distributions — lower value of uniformity factor (*n*) of Rossin–Rammler distribution — compared with pure

Table 5
Uniformity factor of the Rossin–Rammler distribution of the samples

Sample	n	Sample	n	Sample	n
C1-38	1.06	C1L1-35-45	0.78	C2-66	1.02
C1-52	0.99	C1L1-35-60	0.81	C2L1-10-66	0.91
C1-60	0.96	C1L2-10-38	0.90	C2L1-20-66	0.81
C1L1-10-38	0.96	C1L2-10-45	0.86	C2L1-35-66	0.76
C1L1-10-45	0.95	C1L2-10-60	0.86	C2L2-10-66	0.87
C1L1-10-60	0.92	C1L2-20-60	0.77	C2L2-20-66	0.93
C1L1-20-38	0.89	C1L2-35-60	0.71	C2L2-35-66	0.81
C1L1-20-45	0.84	C1L3-10-60	0.83	C2L3-10-66	0.92
C1L1-20-60	0.79	C1L3-20-60	0.81	C2L3-20-66	0.88
C1L1-35-38	0.77	C1L3-35-60	0.75	C2L3-35-66	0.73

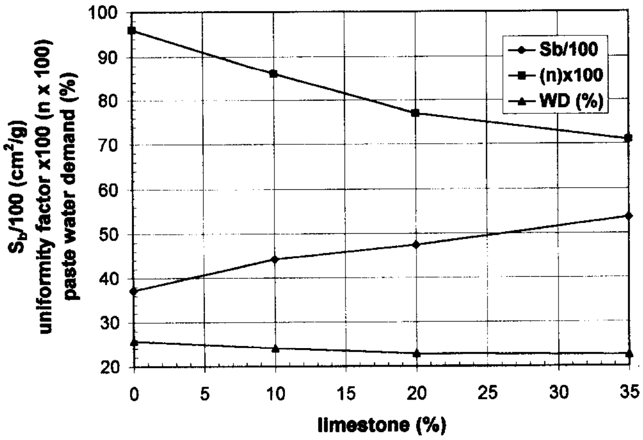

Fig. 8. Cement specific surface, uniformity factor of Rossin–Rammler distribution and paste water demand in relation to the limestone content for the cements C1L2 ground for 60 min.

Table 6
Linear shrinkage/expansion of the samples

Sample	Shrinkage (10^{-6})			Expansion (10^{-6})		
	7 d	14 d	28 d	7 d	14 d	28 d
C1-52	270	420	500	50	60	90
C1L1-10-52	280	390	490	5	20	30
C1L1-20-52	210	280	435	30	40	45
C1L1-35-52	230	330	400	20	30	35
C1L2-35-52	290	410	450	10	15	25
C1L3-35-52	340	390	425	20	25	30
C2-51	390	590	740	50	60	80
C2L1-35-51	260	470	625	40	45	45
C2L2-35-51	290	460	630	30	40	45
C2L3-35-44	460	655	810	10	20	20

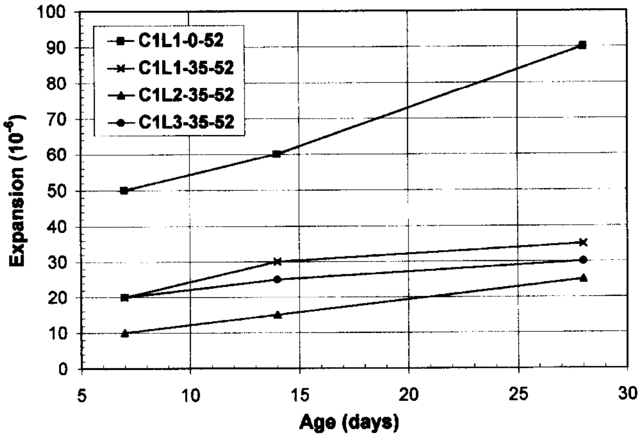

Fig. 9. Linear expansion of cement mortar made from clinker C1 in relation to the curing age and the limestone quality.

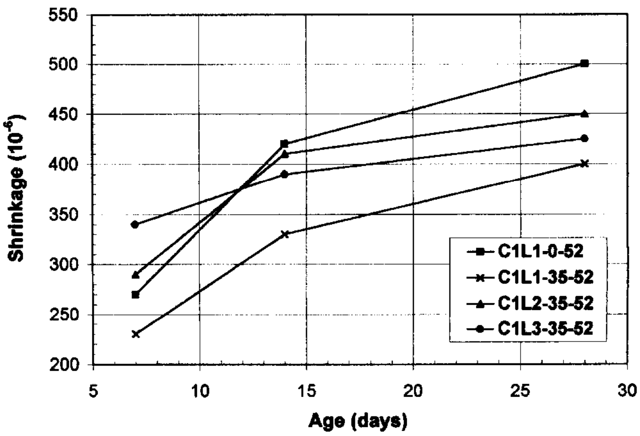

Fig. 10. Linear shrinkage of cement mortar made from clinker C1 in relation to the curing age and the limestone quality.

cements. This is due to the intergrinding of an easy-ground material such as limestone with the clinker. The uniformity factor values of the Rossin–Rammler distribution of the samples are given in Table 5. Figure 8 presents the cement specific surface, the uniformity factor of Rossin–Rammler distribution and the water demand in relation to the limestone content for the cements C1L2 ground for 60 min. The effect of the particle size distribution on the water demand is clearly shown.

The initial and final setting time of limestone cements (Table 4) are similar to those of the relative pure cements.

The soundness of the limestone cements (Table 4) is satisfactory. The expansion measured according to Le Chatelier process varies from 0.5 mm to 1.5 mm while the limit according to prEN 197-1 is 10 mm.

The results of the shrinkage/expansion tests (NF P 15-433) are presented in Table 6. The linear expansion of limestone cement mortars is definitely smaller than that of the relative pure cement (Fig. 9).The effect of limestone addition on the expansion is greater in cements containing clinker C1. As far as the limestone quality is concerned, the limestone L2 causes the greater positive effect when clinker C1 is used (Fig. 9), while the limestone L3 causes the greater effect when clinker C2 is used. The linear shrinkage at 28 days is lower in the limestone cements containing clinker C1 than in pure cements, especially when the limestone L1 is used (Fig. 10). As far as clinker C2 is concerned only the sample C2L3 exhibits greater shrinkage than the pure cement. According to the experimental results, the linear shrinkage/expansion of limestone cement mortars is mainly associated with the clinker and limestone quality.

Reviewing all the above measurements, it is observed that:

1. clinker C2 is generally more reactive than C1 when limestone is present. This can be associated with the higher content of C_3A which, according the literature, reacts with $CaCO_3$ forming carboaluminates,
2. the dolomitic limestone is combined better with clinker having low C_3A content (C1),
3. the effect of fineness on the clinker reactivity and strength development, varies in relation to clinker and limestone quality.

The above remarks lead to the conclusion that the interaction of the two materials, rather than their individual characteristics, must be considered in order to have the best exploitation of clinker hydraulic potential. Thus our research is now focused on the study of hydration mechanism of clinker in the presence of limestone as well as on the granulometric distribution of each component when the mixture is co-ground.

4. Conclusions

The following conclusions can be drawn from the present study:

— The appropriate choice of the clinker quality, limestone quality and % content and cement fineness can lead to a cement production of desired properties.
— Limestone cements, having up to 10% limestone content and fineness up to a limit value, develop almost the same compressive strength, as the corresponding pure cements.
— The strength development of clinker is significantly favored in samples with definite combination of clinker quality, limestone quality and cement fineness.
— The limestone cements, despite their higher fineness, generally have lower paste water demand than the corresponding pure cements.
— The setting time and soundness of Portland limestone cements are satisfactory and similar to those observed in Portland cements
— The linear expansion of limestone cement mortars is definitely smaller than that of the corresponding pure cement at any ages.

In any case, it is the combination of materials that determines the final properties of the limestone cements and not their individual characteristics.

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