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# Technical properties of the blended cements containing limestone pozzolana, and slag

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***Abstract.*** according to the European Standard EN 197-1, there are beside CEM I another types of cement CEM II, CEM III, CEM IV, and CEM V. This main types of cement contains in addition to clinker, another main constituent or more (pozzolanic, autopozzolanic, and fillers).
The aim of the present research work was to study the validity of local raw materials and industrial wastes (limestone, pozzolana and slag) from different areas in Syria as a cement main constituents for production of the blended cements. For that purpose, the investigate was to study the effect of the mineral additions as partially substituted of clinker Portland cement on the:
•Grindability performance.
•Physico-mechanical characteristics.
The tests and the analyses carried out on the produced blended cements showed results satisfactory, Portland-slag cement present of good technical properties, therefore it is recommended to use it in the works massive and constructions of the stoppings and maritime. Cement with the pozzolana him also present of good technical properties and has a good behavior similar that of cement to the slag, and one can use it in the maritime constructions.
These tests enabled us to highlight the use of the local materials raw and industrial as additions for production of the blended cements
***Keywords:*** *Limestone; Natural pozzolana; Slag; Blended cements*.

## I. Introduction

Most cement plants consume much energy and produce a large amount of undesirable products, which affect the environment. In order to reduce energy consumption and $CO_2$ emission and increase production, cement manufacturers are blending or intergrinding mineral additions such as slag, natural pozzolana, sand and limestone [1]

Large number of studies [2,3,4,5,6,7] have shown that natural pozzolana have been widely used as a substitute for Portland cement in many applications because of their advantageous properties which include cost reduction, reduction in heat evolution, decreased permeability and increased chemical resistance. However, they are often associated with shortcomings such as the need to moist-curing for longer time and a reduction of strength at early ages and up to 28 days.

The consumption of calcite, the formation of carbo-aluminates, the acceleration of the hydration of $C_3A$ and $C_3S$, the change in the C–S–H and the formation of transition zone between the filler and cement paste demonstrate the reactivity of limestone fillers [8,9,10] Consequently, this reactivity improves the early strength, but an associated effect of limestone addition is the reduction of later strength by the dilution effect [11]. The European Standard (EN 197-1) [12] identifies two types of Portland-limestone cement containing (6–20%) limestone (type II/A-L) and (21–35%) limestone (type II/B-L), respectively. But, the addition of limestone in concrete increases the chloride ion diffusion depending on the level of addition [13,14]. Also, the serious problem associated with the use of limestone in cement paste mortar or concrete is the formation of thaumasite as a result of sulfate attack at low temperature (below 15 ºC) [15]. In hot arid countries, as typified by North Africa and the Middle East, the mean temperature is greater-than (20 ºC), and the production of Portland Limestone Cement containing up to (20%) of limestone filler has grown during the last years.

There is a general agreement that the principal hydration products formed when blast-furnace slag is mixed with Portland cement and water is essentially C–S-H similar to the compound produced by the hydration of calcium silicates of Portland cement [16]. The rate of hydration of blast-furnace slag is initially lower than that of Portland cement. Thereafter, Portland cement containing blast-furnace slag typically shows a reduction of strength at early ages (7–20 days) and similar or greater strength at later ages. The addition of blast-furnace slag, regardless of composition and replacement level, reduces the permeability and the ionic diffusion of chloride in well-cured concrete. Recently, addition of blast-furnace slag to reduce the damage caused by sulphate attack in concrete containing limestone aggregates has been investigated [17].

In Syria, most of the cement is blended with additions such as limestone and natural pozzolana but slag not used yet. Natural pozzolana is being used for cement manufacture by at least six of the ten Syrian cement plants whereas most of the cement plants is being used limestone just to optimize grindability. These cement plants add usually about (5-22%) of natural pozzolana and (2-5%) of limestone filler as cement replacement by weight. Apart from the internal quality control testing for conformity to standards requirements, no detailed investigation has been done to evaluate the effect of the interaction between limestone and natural pozzolana additions on the properties of cement mortar and concrete. Also, the effect of utilizing both limestone and natural pozzolana on concrete properties is not well documented in the literature.

The objective of this paper is to study the validity of Syrian raw materials and industrial wastes (limestone, natural pozzolana and slag) as a cement main constituents for production of the blended cements. The physico-mechanical properties and grindability performance of the produced blended cements containing (limestone, natural pozzolana and slag) is also studied.

## 2. Materials and methods

### *2.1. Materials*

The cementitious materials used in this study were ordinary Portland cement clinker, gypsum, limestone filler obtained from a good limestone quarry containing 98.28% of $CaCO_3$ in calcite form without clay minerals and quartz as the main impurity and with low TOC content, natural pozzolana containing 38.31% of reactive silica and a granulated blast-furnace slag (BFS) has a chemical modulus (C+M+A/S) of 1.93 and its XRD pattern showed the absence of crystalline compounds and a hump centered on the main peak of melilite at $2\theta = 30.0°$ (d=3.00), characteristic of well quenched slag [18]. The activity index of BFS was 78% at 7 days and 111% at 28 days, indicating a very active slag according to EN 196-1 [19]. The clinker, gypsum and limestone come from a local cement plant (Alarabia company, south Aleppo, Syria), while natural pozzolana was from Tal-dakwa quarry in the south of Syria. Finally, water-cooled slag was obtained from the metallurgic unit of Hama plant in the west of Syria. The chemical composition of all materials is given in Table 1, while the Bogue potential composition and the module of the clinker are given in Table 2. The mineralogical composition of all materials expect gypsum was determined by X-raydiffraction (Bruker AXS D8 with CuKa radiation, operated at 40kV, 250mA) and XRF (Philips, PW 2440 MagiXPRO), presented in Figs. 1, 2, 3 and 4 respectively.

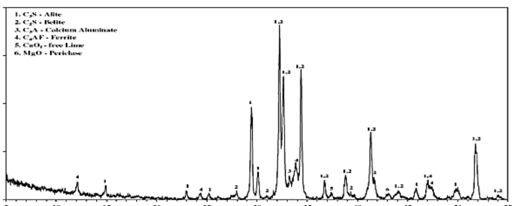

**Figure 1: X-ray diffraction of clinker**

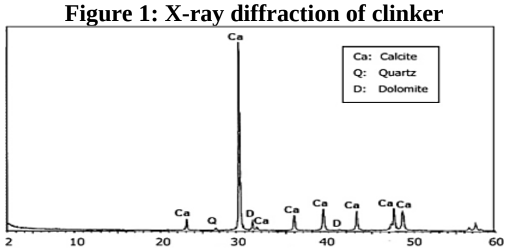


**Figure 2: X-ray diffraction of limestone**

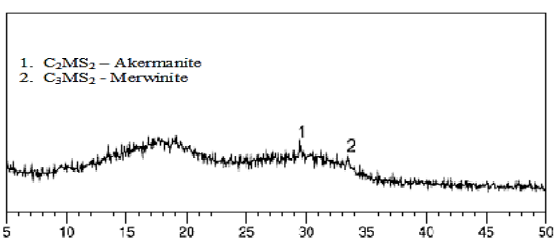


**Figure 3: X-ray diffraction of slag**

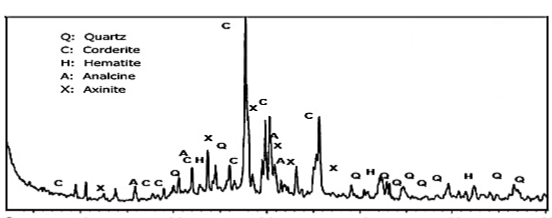


**Figure 4: X-ray diffraction of natural Pozzolana**

**Table I: Chemical composition of materials (%) according to XRF analysis**

| Oxide | Clinker | Gypsum | Limestone | Pozzolana | Slag |
|---|---|---|---|---|---|
| $SiO_2$ | 21.05 | 2.40 | 0.27 | 42.53 | 32.63 |
| $Al_2O_3$ | 4.84 | 0.71 | 0.09 | 12.52 | 14.10 |
| $Fe_2O_3$ | 3.86 | 0.35 | 0.03 | 14.86 | 0.61 |
| CaO | 65.85 | 32.30 | 55.04 | 11.87 | 43.46 |
| MgO | 2.17 | 0.38 | 0.23 | 8.98 | 5.60 |
| $SO_3$ | 0.85 | 42.80 | 0.04 | 0.20 | 0.14 |
| $K_2O$ | 0.31 | 0.10 | 0.03 | 1.47 | 0.39 |
| $Na_2O$ | 0.93 | 0.08 | 0.02 | 3.28 | 0.10 |
| Cl | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| LOI | 0.07 | 20.95 | 43.61 | 2.34 | 1.94 |
| Free Lime | 2.11 | - | - | - | 0.31 |
| Insoluble Residue | 0.26 | - | - | 15.42 | 0.34 |

**Table II: Mineralogical composition (%) and module of clinker**

| Bogue potential composition (%) | | | | Module | | |
|---|---|---|---|---|---|---|
| $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ | LSF | SM | AM |
| 59.49 | 15.50 | 6.28 | 11.76 | 98.04 | 2.42 | 1.25 |

### *2.2. Samples preparation*

One sample of reference Portland cement and three series of blended cements containing 7.5%, 15%, 22.5% and 30% (w/w) supplementary materials (limestone (L), natural pozzolana (P) and slag (S)), respectively, were prepared according to EN 197-1 [12]. Before mixing, gypsum optimization was done for the clinker used and was found to be 4 wt.% of the clinker. Reference sample has been produced by intergrinding clinker (C) and gypsum (G) and designated as OPC. The other series of blended cements were designated as PLC, PPC and PSC. The details of blended cements as well as their physical characteristics are given in Table 3. A pro-pilot plant ball-mill of 5 kg capacity was used for the grinding process. The fineness of the samples was (Blain 3500±100 $cm^2/g$). Chemical analysis of the produced blended cements was conducted by X-ray analysis (XRF) and it is expressed in oxides and presented in Table 4.

**Table III: Physical characteristics of the produced blended cements**

| Symbol | Cement mixes | Residue | | Blain $Cm^2/g$ | Density $g/cm^3$ | $CaO_f$ % |
|---|---|---|---|---|---|---|
| | | 45 µ | 90 µ | | | |
| **OPC** | 4%G + 96% C | 11.50 | 0.80 | 3558 | 3.15 | 2.01 |
| **PLC 7.5%** | 4%G + 88.5% C + 7.5% L | 12.56 | 1.00 | 3618 | 3.12 | 1.82 |
| **PLC 15%** | 4%G + 81% C + 15% L | 13.95 | 1.47 | 3628 | 3.08 | 1.60 |
| **PLC 22.5%** | 4%G + 73.5% C + 22.5% L | 15.01 | 2.01 | 3602 | 3.04 | 1.41 |
| **PLC 30%** | 4%G + 66% C + 30% L | 16.50 | 2.46 | 3613 | 3.00 | 1.20 |
| **PPC 7.5%** | 4%G + 88.5% C + 7.5% P | 11.79 | 0.81 | 3583 | 3.14 | 1.82 |
| **PPC 15%** | 4%G + 81% C + 15% P | 12.21 | 0.89 | 3548 | 3.13 | 1.62 |
| **PPC 22.5%** | 4%G + 73.5% C + 22.5% P | 12.98 | 0.93 | 3614 | 3.12 | 1.43 |
| **PPC 30%** | 4%G + 66% C + 30% P | 13.19 | 1.01 | 3595 | 3.11 | 1.18 |
| **PSC 7.5%** | 4%G + 88.5% C + 7.5% S | 12.11 | 0.86 | 3603 | 3.11 | 1.84 |
| **PSC 15%** | 4%G + 81% C + 15% S | 13.01 | 0.98 | 3538 | 3.06 | 1.67 |
| **PSC 22.5%** | 4%G + 73.5% C + 22.5% S | 13.96 | 1.07 | 3588 | 3.00 | 1.49 |
| **PSC 30%** | 4%G + 66% C + 30% S | 14.88 | 1.15 | 3610 | 2.95 | 1.34 |

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**Table IV: Chemical composition of the produced blended cements (%)according to XRF analysis**

| Symbol | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $K_2O$ | $Na_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|
| OPC | 20.30 | 4.67 | 3.72 | 64.51 | 2.10 | 2.53 | 0.30 | 0.90 | 0.91 |
| PLC 7.5% | 18.64 | 4.29 | 3.42 | 63.64 | 1.95 | 2.46 | 0.28 | 0.83 | 4.39 |
| PLC 15% | 16.98 | 3.91 | 3.11 | 62.78 | 1.79 | 2.40 | 0.26 | 0.75 | 7.87 |
| PLC 22.5% | 15.32 | 3.53 | 2.80 | 61.91 | 1.64 | 2.33 | 0.24 | 0.68 | 11.35 |
| PLC 30% | 13.66 | 3.15 | 2.50 | 61.05 | 1.48 | 2.27 | 0.21 | 0.61 | 14.84 |
| PPC 7.5% | 22.02 | 5.29 | 4.60 | 60.19 | 2.65 | 2.48 | 0.40 | 1.09 | 1.09 |
| PPC 15% | 23.74 | 5.90 | 5.48 | 55.87 | 3.19 | 2.42 | 0.49 | 1.28 | 1.27 |
| PPC 22.5% | 25.46 | 6.52 | 6.36 | 51.55 | 3.74 | 2.37 | 0.58 | 1.46 | 1.45 |
| PPC 30% | 27.18 | 7.13 | 7.24 | 47.23 | 4.28 | 2.32 | 0.67 | 1.65 | 1.63 |
| PSC 7.5% | ٢١,٢٣ | ٥,٤١ | ٣,٤٦ | ٦٢,٧١ | ٢,٣٨ | ٢,٤٧ | ٠,٣١ | ٠,٨٣ | ١,٠٥ |
| PSC 15% | ٢٢,١٦ | ٦,١٥ | ٣,٢٠ | ٦٠,٩٢ | ٢,٦٥ | ٢,٤٢ | ٠,٣٢ | ٠,٧٧ | ١,٢٠ |
| PSC 22.5% | ٢٣,٠٨ | ٦,٨٩ | ٢,٩٤ | ٥٩,١٣ | ٢,٩٢ | ٢,٣٦ | ٠,٣٢ | ٠,٧٠ | ١,٣٥ |
| PSC 30% | ٢٤,٠١ | ٧,٦٤ | ٢,٦٨ | ٥٧,٣٤ | ٣,٢٠ | ٢,٣٠ | ٠,٣٣ | ٠,٦٣ | ١,٥٠ |

### *2.3. Grindability test*

In this paper the intergrinding of clinker with the supplementary materials (limestone, pozzolana and slag) is studied (in independent experiments). For that purpose, two series of blended cements containing 7.5%, 15%, 22.5% and 30% (w/w) supplementary materials, respectively, were prepared by using a laboratory ball mill of 1.5 kg capacity as the following: One series of blended cements was grinded to constant fineness (Blain 3500±100 cm2/g). Second series of blended cements was grinded to constant time (105 min), while reference sample has been produced by intergrinding clinker and gypsum (Blain 3500±100 cm2/g, Grinding time 105 min).

Particles analysis was done by using Alpine sieves with 45 and 90 μm size sieves. The fineness of blended cements was done by using Blain apparatus according to EN 196-6 [20].

### *2.4. Mechanical and Physical tests*

For each blended cement, the required water of standard consistency, setting time, volume expansion and strength were examined in accordance with the European Standard. The strength of the samples was determined according to EN 196-1, mortar was made using a well graded siliceous sand according to the ISO-RILEM guidelines and a cement to sand ratio of 1:3. The water to cementitious material ratio (w/cm) was 0.50. Mixtures were cast into 40 × 40 × 160 mm3 prismatic moulds and mechanically compacted in two layers. After casting, moulds containing the specimens were covered with a plastic sheet and stored in the laboratory environment for 24 h. At this age, specimens were demoulded and immersed in lime saturated water until the age of testing at 20 ± 1 °C. Compression and three point bending tests were conducted at 2, 7, 28, 90, 180 and 365 days of age. The results reported are the average of three flexural specimens and six compression tests.

Initial and final setting times of the cement pastes were determined at 20 ± 1 °C according to the procedure described in the EN 196-3 [21]. The precision of the measurement is ±5 min. For each cement paste, three simultaneous Vicat tests are carried out to determine the average setting time. The water requirement and soundness, determined at 20 ± 1 °C by Vicat probe and Le Chatelier method, respectively, according to EN 196-3 [21]

## 3. Result and dissection:

### *3.1. Grindability performance*

The intergrinding of clinker with the supplementary materials (limestone, pozzolana and slag) at constant fineness value and constant grinding time are presented in Table 5 and illustrates in Figs. 5, 6, 7, 8, 9 and 10. Based on these results and at increasing the substitution percentage of supplementary materials by clinker. It can be noticed the following: *At constant fineness value*, the required grinding time was decreasing gradually and residue on sieves (45, 90 μm) was increasing gradually (Figs. 5, 6 and 7), while *at constant grinding time*, the specific surface was increasing gradually and residue on sieves (45, 90 μm) was decreasing gradually (Figs. 8, 9 and 10).

It is obvious that the PLC requires the lower energy consumption for its grinding while the PSC and PPC the higher one (Fig. 5), and the residue of the cements follows the increasing order: PPC, PSC, PLC (Figs. 6 and 7). On the other hand, the PLC having the higher specific surface while the PSC and PPC the lower one (Fig. 8), and the residue of the cements follows the increasing order: PLC, PSC, PPC (Figs. 9 and 10). Results show the grindability of the used materials follows the decreasing order: limestone, slag, pozzolana, clinker. The limestone is the easier ground material and clinker is the more difficult ground material [22,23].

**Table V: The intergrinding of clinker with the supplementary materials**

| Symbol | Blaine (3500±100 cm²/g) | | | Symbol | Grinding time (105 min) | | |
|---|---|---|---|---|---|---|---|
| | 45um | 90um | Time (min) | | Blaine | 45um | 90um |
| **OPC** | 11.50 | 0.80 | 105 | OPC | 3558 | 11.50 | 0.80 |
| **PLC$_B$ 7.5%** | 12.56 | 1.00 | 95 | PLC$_T$ 7.5% | 3772 | 10.64 | 0.75 |
| **PLC$_B$ 15%** | 13.95 | 1.47 | 85 | PLC$_T$ 15% | 3997 | 9.87 | 0.71 |
| **PLC$_B$ 22.5%** | 15.01 | 2.01 | 75 | PLC$_T$ 22.5% | 4182 | 8.92 | 0.65 |
| **PLC$_B$ 30%** | 16.50 | 2.46 | 65 | PLC$_T$ 30% | 4411 | 8.08 | 0.58 |
| **PPC$_B$ 7.5%** | 11.79 | 0.81 | 101 | PPC$_T$ 7.5% | 3623 | 10.90 | 0.80 |
| **PPC$_B$ 15%** | 12.21 | 0.89 | 91 | PPC$_T$ 15% | 3703 | 10.30 | 0.77 |
| **PPC$_B$ 22.5%** | 12.98 | 0.93 | 81 | PPC$_T$ 22.5% | 3810 | 9.80 | 0.71 |
| **PPC$_B$ 30%** | 13.19 | 1.01 | 71 | PPC$_T$ 30% | 3913 | 9.10 | 0.67 |
| **PSC$_B$ 7.5%** | 12.11 | 0.86 | 98 | PSC$_T$ 7.5% | 3689 | 10.91 | 0.78 |
| **PSC$_B$ 15%** | 13.01 | 0.98 | 88 | PSC$_T$ 15% | 3780 | 10.10 | 0.73 |
| **PSC$_B$ 22.5%** | 13.96 | 1.07 | 78 | PSC$_T$ 22.5% | 3875 | 9.32 | 0.67 |
| **PSC$_B$ 30%** | 14.88 | 1.15 | 68 | PSC$_T$ 30% | 3967 | 8.34 | 0.61 |

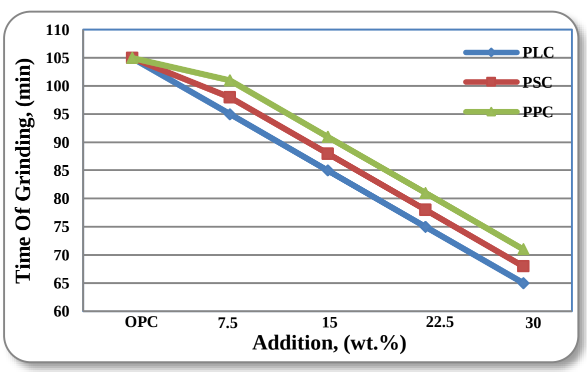


**Figure 5: Decreasing of grinding time at constant fineness value**

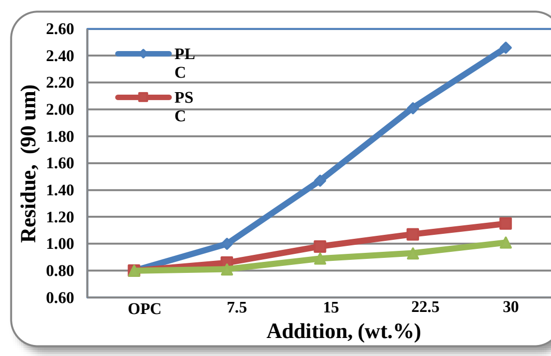


**Figure 7: Increasing of residue (90 um) at constant fineness value**

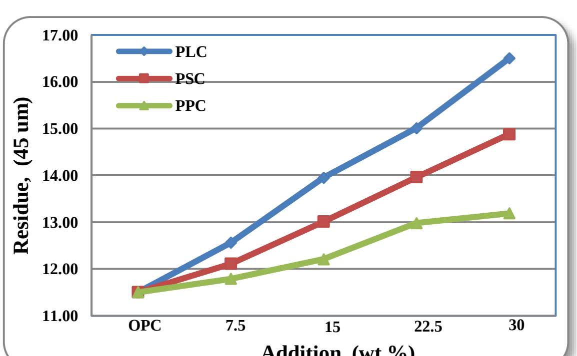


**Figure 6: Increasing of residue (45 um) at constant fineness value**

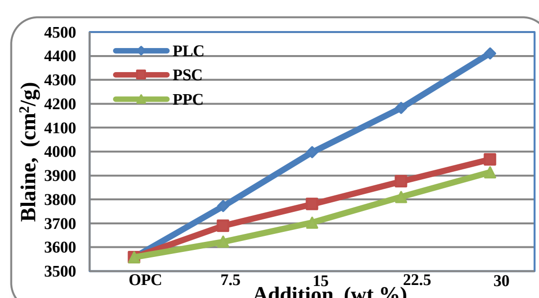


**Figure 8: Increasing of fineness value at constant grinding time**

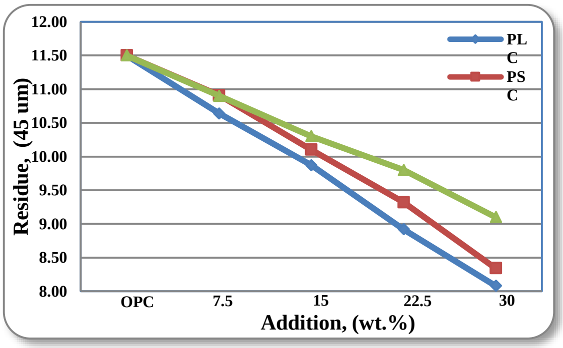


**Figure 9: Decreasing of residue (45 um) at constant grinding time**

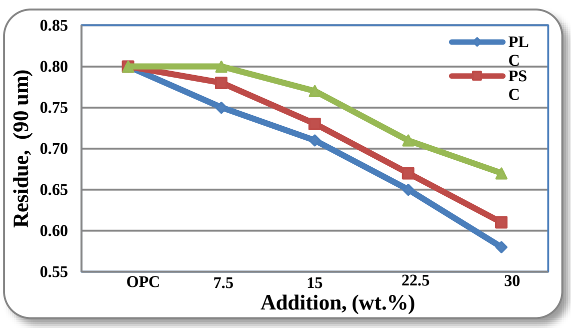


**Figure 10: Decreasing of residue (90 um) at constant grinding time**

**Figure 10: Decreasing of residue (90 um) at constant grinding time**

### *3.2. Mechanical properties*

Table 6 reports the mean value of flexural and compressive strength for cements used at all ages. The typical strength development of the tested cements at each age is illustrated in Figs. 11, 12, 13, 14, 15 and 16. Based on the experimentally obtained results, it can be noticed the following: All strengths of the produced cements was decreasing gradually at increasing the substitution percentage of supplementary materials with clinker and at constant fineness value. The interesting point is the strength development rate before and after 28 days. Up to 7 days, it is clearly observed that Portland limestone cement (PLC) exhibited the highest value of compressive strength, while the Portland pozzolana cement (PPC) showed the lowest value of compressive strength. The reasons behind the above behavior can be attributed to the contribution of limestone filler to hydration acceleration at early ages and the low rate of the pozzolanic reaction. The strength development between 7 and 28 days seems to be good in all cements. However, the strength development is higher in PSC than the rest studied cements. For the period 28–365 days, the strength development is very significant in the case of PSC then PPC, while PLC showed the lowest rate of strength development. At later ages, the BFS produces a cementing material (C–S–H) that improves the pore filling and enhances the strength. But the limestone has no hydraulic properties in comparison with slag and pozzolana, so an associated effect of limestone addition is the reduction of later strength

**Table VI: Compressive and flexural strengths of the produced blended cements**

| Sample | Flexural Strength (N/mm²) | | | | | | Compressive Strength (N/mm²) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 d. | 7 d. | 28 d. | 90 d. | 180 d. | 365 d. | 2 d. | 7 d. | 28 d. | 90 d. | 180 d. | 365 d. |
| **OPC** | 5.30 | 6.00 | 7.20 | 7.60 | 7.70 | 7.73 | 23.10 | 38.70 | 50.30 | 56.00 | 57.55 | 58.12 |
| **PLC 7.5%** | 4.30 | 5.70 | 6.60 | 6.70 | 7.00 | 7.03 | 22.80 | 36.20 | 43.10 | 47.00 | 48.10 | 48.58 |
| **PLC 15%** | 4.10 | 5.20 | 5.90 | 6.40 | 6.50 | 6.52 | 20.30 | 30.50 | 37.90 | 42.60 | 43.70 | 44.14 |
| **PLC 22.5%** | 3.40 | 4.40 | 5.60 | 5.80 | 5.90 | 5.94 | 16.50 | 26.70 | 33.00 | 35.60 | 36.50 | 36.86 |
| **PLC 30%** | 2.30 | 3.70 | 4.50 | 4.70 | 4.90 | 4.92 | 12.50 | 22.30 | 28.00 | 29.90 | 31.00 | 31.31 |
| **PPC 7.5%** | 4.00 | 5.35 | 6.10 | 6.70 | 7.20 | 7.24 | 19.55 | 33.00 | 46.50 | 52.10 | 54.80 | 56.44 |
| **PPC 15%** | 3.50 | 4.60 | 5.70 | 6.30 | 6.90 | 6.93 | 16.90 | 26.50 | 40.00 | 48.00 | 50.85 | 52.37 |
| **PPC 22.5%** | 2.90 | 4.00 | 5.00 | 5.90 | 6.30 | 6.34 | 13.95 | 22.00 | 35.10 | 44.10 | 46.95 | 48.36 |
| **PPC 30%** | 2.10 | 3.40 | 4.50 | 5.20 | 5.80 | 5.82 | 8.81 | 17.50 | 31.40 | 38.20 | 41.30 | 42.95 |
| **PSC 7.5%** | 4.30 | 5.50 | 6.80 | 7.20 | 7.40 | 7.44 | 21.30 | 35.60 | 48.30 | 56.40 | 59.30 | 61.08 |
| **PSC 15%** | 3.80 | 4.70 | 6.20 | 7.00 | 7.10 | 7.14 | 18.00 | 28.70 | 43.10 | 53.20 | 57.50 | 59.80 |
| **PSC 22.5%** | 3.10 | 4.20 | 5.70 | 6.10 | 6.50 | 6.55 | 15.20 | 25.50 | 40.70 | 47.30 | 50.60 | 52.12 |
| **PSC 30%** | 2.60 | 3.80 | 5.30 | 5.70 | 6.00 | 6.07 | 10.80 | 20.10 | 35.00 | 41.40 | 44.10 | 45.42 |

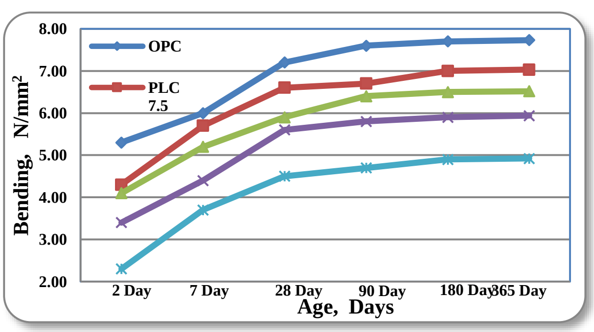


**Figure 11: Flexural strength of the cement samples containing limestone**

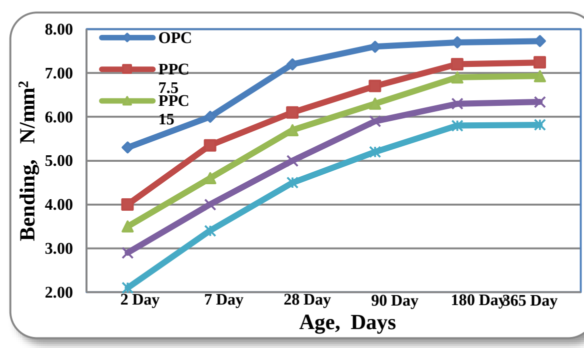


**Figure 13: Flexural strength of the cement samples containing pozzolana**

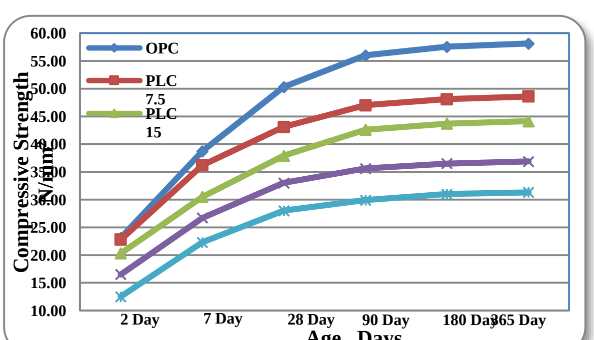


**Figure 12: Compressive strength of the cement samples containing limestone**

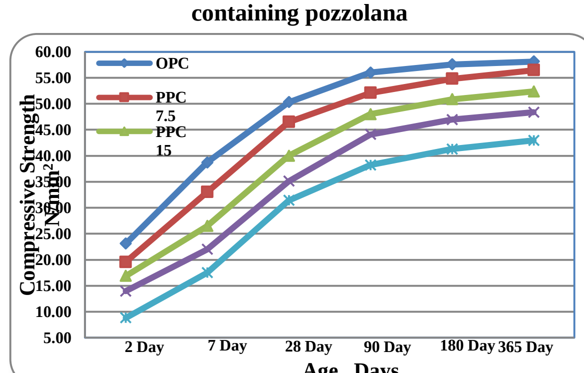


**Figure 14: Compressive strength of the cement samples containing pozzolana**

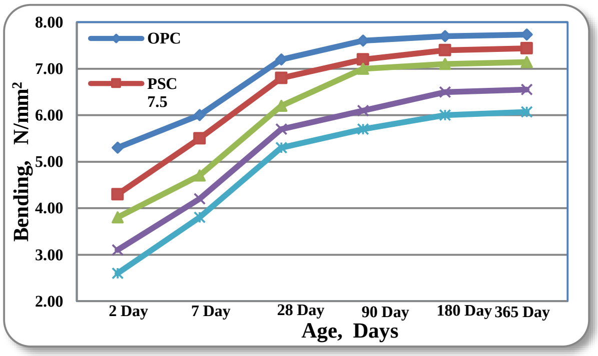


**Figure 15: Flexural strength of the cement samples containing slag**

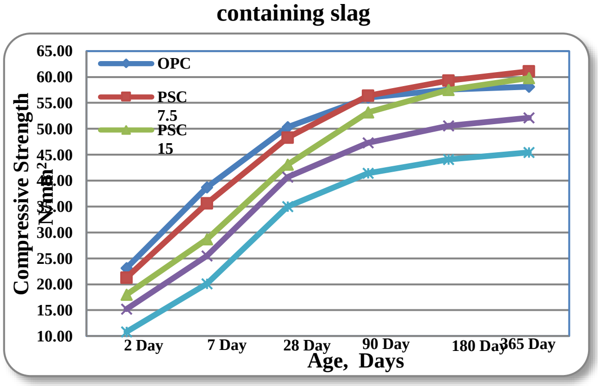


**Figure 16: Compressive strength of the cement samples containing slag**

### *3.3. Physical properties*

Table 7 shows the test results from the determination of water-percent, setting time and volume expansion for cement mixes. The results reveal that the water of consistency as well as the setting time of cement pastes slightly decreases with limestone content. This is because the addition of limestone increases the plasticity of cement paste. This may be attributed to the effect of limestone as an active component in the hydration of Portland cement, i.e. the rate of hydration increases and the amount of the hydration products enhances. The limestone acts a nucleating agents which increases the hydration rate of cement phases. Also, the limestone forms monocarboaluminate hydrate that needs less water than that of ettringite. On the other hand, it is clear that the use of pozzolana in cement decreases the water of consistency, while the use of slag in cement increases it and both resulted in a prolonged initial and final setting times with respect to corresponding Portland cement. This is mainly due to the pozzolanic reaction contribution of pozzolana and hydraulic properties of slag. These results are in good agreement with those reported elsewhere

The effects of replacement materials on the volume expansion of cement paste are shown in Table 7. The results indicate that the replacement of pozzolana and slag by clinker reduces expansion, while the replacement of clinker by limestone increases expansion compared to control cement past without supplementary materials. Moreover, there is a slight decrease or increase in the expansion as the supplementary materials content increases ranging from 7.5% to 30%. This behavior is typical of the supplementary materials used in the earlier study and reported elsewhere. The decrease or increase in the expansion may be attributed to the CaO content of the supplementary materials. The soundness of the all produced blended cements is satisfactory, the expansion measured varies from 0.95 mm to 2.94 mm, while the limit value prescribed by EN 197-1 is 10 mm

**Table VII: Physical characteristics of cementitious mixes**

| Sample | Water Demand (%) | Setting Time (min) | | Expansion (mm) |
|---|---|---|---|---|
| | | Initial | Final | |
| **OPC** | 29.90 | 220 | 300 | 1.80 |
| **PLC 7.5%** | 29.30 | 213 | 295 | 1.99 |
| **PLC 15%** | 28.71 | 204 | 288 | 2.26 |
| **PLC 22.5%** | 28.14 | 193 | 283 | 2.53 |
| **PLC 30%** | 27.58 | 185 | 276 | 2.94 |
| **PPC 7.5%** | 29.51 | 228 | 319 | 1.60 |
| **PPC 15%** | 29.11 | 241 | 335 | 1.37 |
| **PPC 22.5%** | 28.73 | 267 | 355 | 1.19 |
| **PPC 30%** | 28.33 | 288 | 381 | 0.97 |
| **PSC 7.5%** | 30.41 | 225 | 305 | 1.58 |
| **PSC 15%** | 30.96 | 237 | 322 | 1.36 |
| **PSC 22.5%** | 31.49 | 255 | 341 | 1.17 |
| **PSC 30%** | 32.04 | 276 | 367 | 0.95 |

## 3. Conclusion:

The introduction of the mineral additions to cement tends to be concretized more and more to improve quality of the concrete and to increase the quantity of production all in decreasing the consumption of the clinker, this presents an economic interest for the national cement companies and participles at the environment.

The additions which can be used for the manufacture of cements are classified in two main categories, which are the active additions and interns.

While varying the type of addition, one could especially obtain various types of cements with physico properties mechanical satisfactory in the corrosive conditions.

In our work, the tests and the analyses carried out on the produced cements showed results satisfactory. These tests enabled us to highlight the use of the local additions for production of the blended cements.

Portland-slag cement present of good technical properties, therefore it is recommended to use it in the works massive and constructions of the stoppings and maritime.

Cement with the pozzolana him also present of good technical properties and has a good behavior similar that of cement to the slag, and one can use it in the maritime constructions.

For cements with the inert additions have a good technical properties.

Finally, from the above finding, it can be concluded that the local raw materials and industrial wastes (limestone, pozzolana and slag) suitable as a cement main constituents for production of the blended cements.

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# الخواص التقنية للإسمنتات المخلوطة المحتوية على الحجر الكلسي، البوزولانا، خبث الحديد الثنائي

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**مستخلص**. وفقاً للمواصفة القياسية الأوروبية EN 197-1 ، يوجد بجانب CEM -1 أنواعاً أخرى من الإسمنتات CEM II، CEM III، CEM IV، CEM V تحتوي هذه الأنواع الرئيسية من الإسمنت بالإضافة للكلينكر، مكون رئيسي آخر أو أكثر مثل: مواد بوزولانية، مواد بوزولانية مائية، مواد حشوة.

هدف البحث الحالي، دراسة صلاحية الخامات المحلية والمخلفات الصناعية (الحجر الكلسي، البوزولانا، الخبث) من مناطق مختلفة في سوريا كمكونات رئيسية للإسمنت لإنتاج الإسمنتات المخلوطة. لهذا الغرض، كان التحري لدراسة تأثير الإضافات المعدنية كبديل جزئي عن كلينكر الإسمنت البورتلندي على:

1-إداء قابلية الطحن.

2-الخصائص الميكانيكية والفيزيائية.

بينت الاختبارات والتحاليل المنفذة على الإسمنتات المخلوطة المنتجة نتائج مقنعة، فإسمنت الخبث البورتلاندي له خصائص تقنية جيدة ، لذلك يوصى باستخدامه في الأعمال الضخمة والسدود البحرية، الأسمنت مع البووزولانا يتمتع بخصائص تقنية جيدة وله سلوك جيد مشابه لسلوك إسمنت الخبث ، ويمكن للمرء استخدامه في الإنشاءات البحرية حيث مكنتنا هذه الاختبارات من تسليط الضوء على استخدام الخامات المحلية والمخلفات الصناعية كإضافات لإنتاج الإسمنتات المخلوطة.

**كلمات مفتاحيه:** الحجر الكلسي، البوزولان الطبيعي، الخبث، الإسمنتات المخلوطة.

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