Durability of Normal and Lightweight Aggregate Mortars with Different Supplementary Cementitious Materials

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Abstract: - A study on the durability parameters of normal and lightweight aggregate mortars, incorporated different supplementary cementitious materials (SCM) is presented. Mortars were prepared using limestone or pumice as aggregates and Metakaolin, Fly ash, Granulated Blast Furnace Slag and Silica Fume, as SCM, that they replaced cement, at 10 % by mass. Ten different mortars, having same water to binder ratio and aggregate to cement volumetric ratio, they were compared mainly in terms of durability. The use of pumice sand was proved to be effective not only to the density of the mortars as it was expected, but also in durability, fulfilling at the same time minimum strength requirements. The addition of the different SCM further enhanced the durability of the mortars, where Metakaolin was found to be the most effective one, especially against chloride's ingress.

Key-Words: - Lightweight Aggregate Mortars, Silica Fume, Fly ash, Granulated Blast Furnace Slag, Metakaolin, Durability.

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1 Introduction

Mortar, after concrete, is the second building material with a wide usage in construction. Complementary to its wide use since ancient times [1] as an adhesive mortar, it is also used for rendering walls and concrete frame surfaces, for both architectural and durability purposes [2]. Thus, mortar ought to perform as an important barrier against chloride ingress and carbonation, the two critical aiding mechanisms of steel corrosion [3].

Typical mortar mix contains at least three constituents, a binder (i.e. cement, lime), sand and water [4]. River or limestone sand is commonly used as both mortar and concrete aggregates and the construction activity consumes them significantly, worldwide. Thus, aggregates instead of concrete are after water the most consumed materials, contrary to the general belief [5].

The use of alternative aggregate sources will promote sustainability. To this aim, artificial lightweight aggregates (LWA), which they are often made of industrial by-products, are used [6]. Their incorporation in concrete lowers its Environmental Impact (EI), despite the fact that EI of concrete is mainly burdened by cement [7].

Natural lightweight aggregates (LWA) are also used in mortar and concrete. Although they do not decrease the EI of concrete as much as the artificial LWA do, they also contribute to sustainability, since they widen the exploitation of aggregates natural resources. In addition, concrete with lightweight aggregates (LWAC) also favours sustainability, as its decreased weight results in reduced seismic loads, leading to economical design, accomplishing at the same the structural requirements of Eurocodes [8]. Moreover, LWAC has better thermal and sound insulation characteristics [9].

Pumice, a natural lightweight aggregate of volcanic origin, has a wide use in construction, because of its density, pozzolanicity and strength. It is a well-known lightweight concrete aggregate for over 2000 years [10].

As aggregates characteristics considerably influence the properties of the mortar, pumice LWA concrete and mortars need also investigation in terms of strength and durability. Aggregates grading characteristics is known that affect workability, binder consumption and therefore total cost [11]. Sand type (i.e. normal or lightweight) also regulates density and thermal characteristics [12]. Furthermore, shape and surface texture, affects water demand, strength and durability. Similarly, the incorporation of pumice reduces workability, density and strength [10]. Thus, it is more than essential to study the effect that the lightweight aggregates have on the strength and durability of the mortars.

Furthermore, in order to assure strength and durability of LWA mortars the usage of supplementary cementitious materials (SCM) is promoted. The results showed that strength of LWA concrete, as well as durability were improved by the usage of SCM. For instance, LWAC with silica fume exhibits high compressive strength, improved resistance to chloride permeability and diffusion and decreased sorptivity [13]. However, further justification of the expected positive effects of different SCM use in mortar and concrete will be valuable. Moreover, as chloride penetration resistance is assessed as one of the most important durability parameter [3][14], further research is elemental.

Chloride penetration resistance of concrete is often evaluated by acceleration tests, such as rapid chloride penetration test (RCPT) and chloride migration test (CMT) [15][16]. Although, these methods are not able to describe chlorides diffusion. The chloride diffusion tests [17] is considered that they are closer to real structure phenomena, but of course when the saturation of concrete occurs. In a full saturated concrete, penetration of chlorides is considered as the driven mechanism that governs the diffusion [18]. Then chloride diffusion coefficient is calculated by the solution of the Fick's second law.

In this study, a comparison is performed in terms of durability, between normal weight and lightweight aggregate mortars that they incorporate SCM, such as metakaolin, fly ash, granulated blast furnace slag and silica fume. The comparison results will be used to support the main benefits of the LWA usage in mortars (lower weight/thermal insulation), together with the strength requirements fulfilment. Chloride penetration and diffusion resistance, as well as open porosity and sorptivity, are the main durability parameters that they were investigated.

2 Experimental

2.1 Materials and Mixtures

Typical Portland cement (CEM I 42.5 N) was used (C), according to EN 197-1:2011 [19], in all the reference mortars (N/L-REF), while in some mortar mixtures, it has been replaced at 10% by SCM, such as Silica Fume (SF), Metakaolin (MK), Granulated Blast Furnace Slag (GS) and Fly Ash (FA). The chemical analysis of cement and SCM is presented in Table 1. As far as MK is concerned, the chemical analysis of the kaolin (K) used for the production of MK, is instead given. K is expected to be of high purity, since the Al_2O_3 is high. On the other hand, FA contains less than 20% CaO and and it can be classified as Type F according to ASTM C 618, ($SiO_2 + Al_2O_3 + Fe_2O_3 > 70\%$).

For the mortar preparation, calcareous (Ca) normal weight and pumice (Pu) lightweight sand of locally available crushed calcareous limestone and pumice deposits respectively, were used. Aggregate and cement physical characteristics are presented in Table 2.

Table 1: Oxide content (% w/w) in cement and SCM.

Comp.	**C**	**K**	**FA**	**GS**	**SF**
SiO_2	20.1	48.0	47.2	50.7	95.1
Al_2O_3	4.9	38.4	21.1	40.9	0.7
Fe_2O_3	3.5	1.3	9.8	0.8	0.6
CaO	62.2	-	13.8	0.4	0.3
MgO	3.1	-	2.2	6.2	-
K_2O	0.5	-	1.4	0.3	0.4
Na_2O	0.2	-	0.2	-	-
SO_3	2.7	-	2.4	0.5	-
TiO_2	-	-	-	-	-
L.O.I.	2.8	12.3	1.9	0.2	3.0

Table 2. Physical characteristics of cement (C) Pumice (Pu) and Calcareous sand (Ca).

	C	**Pu**	**Ca**
ρ_a (g/cm^3)	3.15	1.61	2.61
Water absorption (%)	-	19.25	2.14
Specific surface (m^2/g)	0.40	-	-

Grading characteristics of aggregates are presented in Figure 1. As it is shown, both aggregates have maximum size of 4 mm. They exhibit differences in the size distribution, especially regarding the amount of particles sized greater than 0.5 mm. Pumice sand is finer than the calcareous one and it is expected that mortar will demand additional water. Certainly, it is the porous nature of the pumice sand which mainly affects the water suspension of the mixture. Pumice sand has a significantly higher water absorption capacity (Table 2) and it is expected to affect the rheology of the mixture. Thus, the usage of superplastisizers (SP) will be necessary in order correct any imbalances in the rheology of the mixtures and to achieve similar grade of compactness among them.

Finally, granular characteristics for the used SCM are summarized in Table 3. The specific surface of cement, is also reported to be 0.40 m^2/g. It is show that SF is the finer material, having less than 1% particles coarser than 10 μm.

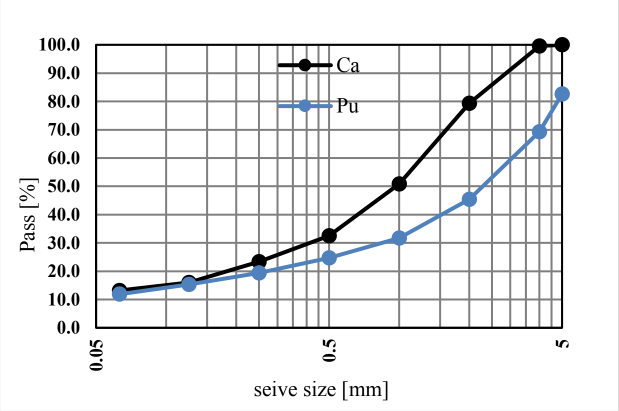

Fig.1. Grading curves of calcareous and pumice sand.

Table 3. Granular size characteristic values of the SCM.

SCM	d_{10} (μm)	d_{50} (μm)	d_{90} (μm)
MK	0.95	5.10	12.93
SF	0.07	0.15	0.34
FA	2.03	19.24	63.45
GS	2.09	24.17	74.08

Regarding the mineralogy of pumice and SCM, Pu, although mainly amorphous, it contains potassium feldspar (Sanidine) and quartz. MK, which it is commercially (Imerys Minerals) produced from kaolin (K), is also amorphous. Traceable amounts of illite and quartz are also found. In FA which it is stem from the power plant of Megalopolis (Greece), the main mineralogical phases found, are feldspars, maghemite, quartz, anhydrite, cristobalite, zeolites, gehlenite and carbonates. GS reported mainly amorphous and contained also calcite. Finally, the SF is commercial product and it is completely amorphous.

The combination of all materials, yielded ten different mortar mixtures, five for each aggregate type. Their nomination and mixing details are presented in Table 4. Special care was taken in order to maintain the same volume ratio of cement to aggregates, equal to 1:3.6 (approx.) in both NW and LW mortars and SCM were added in the mixtures replacing cement at 10% by mass. The use of such fine materials as SCM, increases the water demand of the mixtures and in order to maintain the water-to-binder ratio (w/b) at 0.55, a (Sika Viscocrete) superplastisizer (SP) was used. Thus, the workability was controlled using the slump values of the mortars as a guide property and as it is shown in Table 4, different SP dosage was used, depending on the type of both aggregates and SCM.

Cubes 50x50x50 mm^3 and cylindrical specimens Ø100x200 mm were casted for the strength and durability tests. The samples were demoulded one day later and all the specimens were cured for 90 days, in water tanks at 23±1 °C.

Table 4. Lightweight (LW) and normal weight (NW) mortars, with pumice and limestone sand, respectively.

(g)	**LW Mortars**					**NW Mortars**				
	LW-REF	**LW-MK**	**LW-FA**	**LW-GS**	**LW-SF**	**NW-REF**	**NW-MK**	**NW-FA**	**NW-GS**	**NW-SF**
C	1799	1619	1619	1619	1619	1710	1539	1539	1539	1539
Pu	3334	3334	3334	3334	3334	-	-	-	-	-
Ca	-	-	-	-	-	5130	5130	5130	5130	5130
MK	-	180	-	-	-	-	171	-	-	-
FA	-	-	180	-	-	-	-	171	-	-
GS	-	-	-	180	-	-	-	-	171	-
SF	-	-	-	-	180	-	-	-	-	171
W	989	810	810	810	810	940	769	769	769	769
SP (%)*	0.5	0.7	0.8	0.7	1.5	-	0.6	0.5	0.5	0.9
W/B	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
W/C	0.55	0.50	0.50	0.50	0.50	0.55	0.50	0.50	0.50	0.50

**as a percentage of cement weight, (%, w/w)*

2.2 Testing

The mini slump test on the ten (10) different mortar mixtures was used for the evaluation of the mixtures rheology [20]. Compressive strength was determined using cubic specimens of 50 mm edge, at 2, 7, 14, 28 and 90 days. At every age, three specimens were tested and the strength was calculated as a mean value. Durability parameters like water absorption (open porosity and capillary absorption), chloride ions penetration and diffusion resistance were evaluated for mortar specimens of 28 days age.

Open porosity (OP, %) was measured in accordance with ASTM C 642 [21]. Sorptivity (*S)* was also measured in specimens from each mixture at the age of 28 days, as it is described in [22]. Cylindrical specimens of Ø100x50 mm height, water sealed only on their lateral surfaces by a rainproof tape, were used. Thus, uniaxial water absorption has been assured and the weight changes due capillary absorption were recorded, in discrete time intervals.

The resistance to chloride penetration was valued by calculating the chloride penetration coefficient, D_{nssm} ($\times 10^{-12}$ m^2/s), establishing non-steady-state experimental conditions [23]. Similarly to sorptivity cylindrical specimens of Ø100x50 mm height, extracted from the middle zone of a cylindrical specimen, was subjected for 24 h at a potential difference established between an anode solution of sodium hydroxide (NaOH), 0.3 N and a cathode solution of 10% sodium chloride (NaCl), by mass. All the specimens had the same pre-conditioning, i.e. fully water saturated until the test day.

The chloride penetration depth was measured by a colorimetric method, as soon as the test was completed [24]. Thus, after the test, the specimens were split into two pieces and each of the two split surfaces was sprayed with a 0.1 M silver nitrate ($AgNO_3$) solution. The mean depth of chloride ingress was found by the colour change occurred by the reaction of the chlorides present, with the $AgNO_3$, which produces silver chloride (AgCl). Then, calculation of the coefficient D_{nssm} was made, following the NordTest Build 492 method [23].

The NordTest 443 [17] method was followed for the evaluation of the chloride diffusion off mortars. Slices from the cylindrical specimens (Ø100x200 mm), having a 50 mm height, that they were cured in a lime saturated water solution for 3 months, were used. Details on the sample procedure are described in the standard [17]. A salt solution at a temperature range of 20-25°C, that contained 165 g/l NaCl was used for the exposure. After totally 90 days of exposure in the salt solution, core samples were taken at every 2 mm depth and until a total depth up to 16 mm was reached. In total eight different cores Ø60 of 2 mm height were drilled from the center of the cylindrical face, under a precisely depth controlled procedure and by taking all the necessary precautions in order to avoid intermixing between the samples. It must be noticed that for the same sample volume (Ø60x2 mm) taken from both LW and NW mortars and considering that their mixtures were designed to have same volumetric ratio of cement to aggregates, the cement to aggregates mass ratio is higher in the case of LW mortars (1:2) samples compared to NW mortars (1:3), due to the lower density of the pumice. As a result, more cement paste will be contained in LW samples compared to NW samples.

Next, samples were analysed following the procedure that EN 196-2: 2005 [25] prescribes and the chloride content of each sample was evaluated. The calculation of intrinsic effective chloride transport coefficient (D_e) was assessed by means of the least-square method, where the chloride content results were fitted to the solution of the Fick's second law of diffusion (1).

$$C_{(x,t)} = C_s\left(1 - \operatorname{erf}\left(\frac{x}{2\sqrt{D_e t}}\right)\right) \qquad (1)$$

x: depth (mm)

t: exposure time (s)

$C_{(x,t)}$: concentration (%) of Cl^- at depth x, after t

C_s: concentration (%) of Cl^- at the surface (x=0)

erf: error function

D_e: diffusion coefficient (m^2/s)

More specific, for the total exposure time (90 d) and for the fixed values of depth according to the sampling plan, as well as considering the surface concentration $C_{(x,t)}$ of the samples equal to this of the solution, the D_e values were fitted, in such a manner, as to minimize the deviation between the experimental and the calculated values. Excel Solver optimization tool was used for the fitting procedure.

3 Results and Discussion

Table 4 contains data on the SP usage (% w/w of cement) and Table 5 presents the mini slump experimental results and the density of fresh and hardened mortars, respectively. The addition of the SCM decreases the rheology of the mortars and additional amount of SP was used in order to maintain the same workability. Especially for the SF and MK, which they have explicitly high fineness and consequently high surface area, their incorporated mortars demand higher than usual water in order to become wet. Therefore, in both LW and

NW mortars, reduced workability is expected. On the other hand, since FA and GS are coarser (Table 3) the workability of their mixtures is expected to be better [26][27].

Table 5. Slump values of fresh mortars and density values of hardened mortar samples.

Mortar	Mini Slump Test (cm)	Density (g/cm^3)
LW-REF	19.8	1.63
LW-MK	17.5	1.64
LW-FA	19.3	1.68
LW-GS	19.3	1.68
LW-SF	21.0	1.65
NW-REF	17.6	2.19
NW-MK	15.4	2.20
NW-FA	16.9	2.19
NW-GS	19.5	2.20
NW-SF	16.3	2.19

Indeed, the use of surplus amount of SP was needed in order to preserve the slump at the range of 18 ± 3 cm. Comparing mortars with different SCMs, SF and MK mortars demanded higher SP amounts than the FA and GS mortars. Moreover, SF, in both LW and NW mortars consumed the maximum SP dosage. Especially in the case of LW mortars the dosage of SP is relatively increased compared to NW mortars, since the porous nature of the pumice sand, instantly reduces the available mixing water, although special care was taken and the absorption water of the aggregates (Table 2) was added in advance. Anyhow, by using relatively low amounts of SP (Table 4), the rheology of the mortars was successfully regulated.

As far as the density of the mixtures is concerned, it is obvious that the use of pumice sand resulted in the decrease of the density of the mortar. Density of the LW mortars reported at the range of 1.6 g/cm^3, reduced by 25% compared to the density of the NW mortars (~2.2 g/cm^3). Depending on pumice aggregate max size and therefore its density and of course on its amount, different dry densities could be achieved, ranging between 0.9-1.3 g/cm^3 [28]. In this study, the air density of the mortars is reported higher since only pumice sand is used.

Table 6 and Figure 2 show the results on the compressive strength of the mortars. According to the 28 days compressive strength results presented in Table 6, both LW and NW mortars achieved much higher than 20 MPa strength, which designates the last nominal strength class (M20) of masonry mortars.

Table 6. Average compressive strength, (fc) and standard deviation (Std) of LW and NW mortars, at the age of 28 days.

MORTAR	F_C (MPA)	STD (MPA)
LW-REF	31.74	0.28
LW-MK	36.84	2.07
LW-FA	33.63	2.00
LW-SF	35.72	0.79
LW-GS	32.25	0.20
NW-REF	53.60	1.63
NW-MK	74.63	1.71
NW-FA	56.33	1.34
NW-SF	58.92	4.34
NW-GS	63.33	1.07

The expected and well reported [26][27] in the literature positive effect of SCM additions is evident. More specific, as it is depicted in Figure 2, after 28 and 90 days of curing the addition of MK at 10 % showed the higher positive influence compared to the other SCM, in both NW and LW mortars. An increase of 16% and 25% of the compressive strength at the age of 28 days is reported for the NW and LW, mortars respectively, containing MK. The positive role of MK in strength development is well established in the literature [26,27,29–31]. In the case of LW aggregate concrete, the effect of MK to strength seems to be sensitive to the type of fine aggregate and thus has been reported to range from 22 to 74% [32]. In the case of SF addition, the increase of the compressive strength was ranged above 10% for both NW and LW mortars.

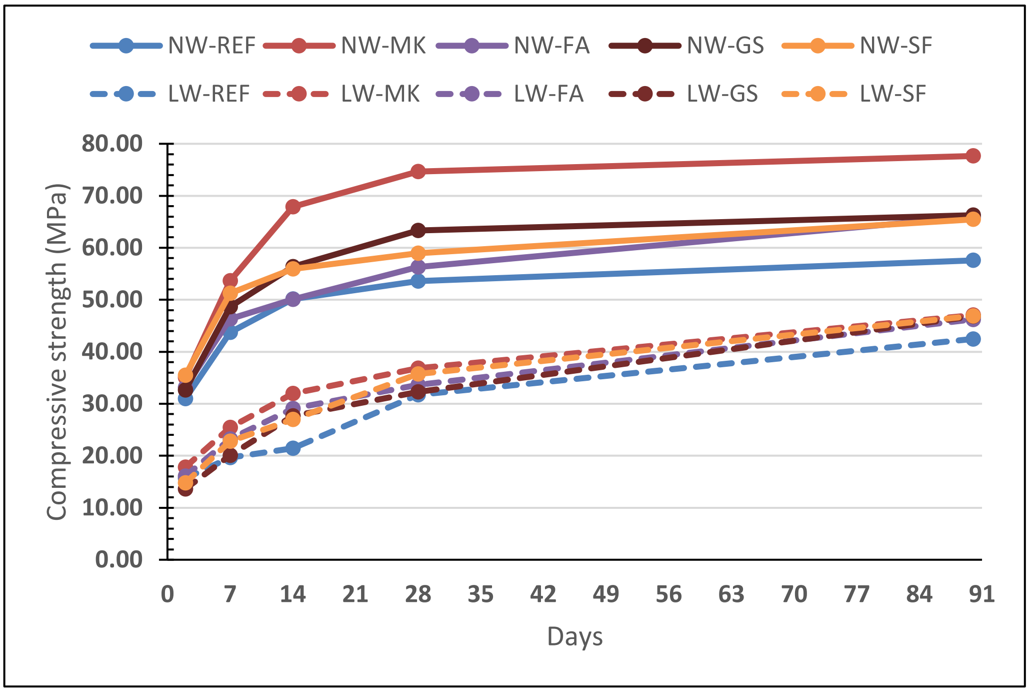

Figure 2. Compressive strength development of NW and LW mortars.

The addition of SF always enhance the strength of mortars and concrete [33] and SF competes MK in terms of strength enhancement, where it is mostly found in the literature to be more effective [26]. Herein, MK seems to be better performed in strength. On the other hand, low increase is achieved in the compressive strength after the addition of 10% FA as well as in the case of GS addition. Strength increase reported marginal for both cases of FA and GS addition (~5 and 2%, accordingly) in the LW mortars, results that they are in agreement with the literature [26]. In contrast, strength gain was counted significant (18%) in the case of NW-GS samples mortars.

Comparing the different mortars with respects to their aggregates type, NW mortars developed higher strength values compared to LW mortars, as a result of the higher strength of the limestone aggregates. Consequently, the effect of SCM addition proved to be more effective in the NW mortars than in the LW mortars. On the other hand, it is noticeable that in the case of the LW mortars, significant increase on compressive strength due to the SCM addition, has been evident after 28 days of curing. As it is shown in Figure 2, the inclination of LW mortars' strength curves is sharper and the compressive strength values at 90 days increased compared to those at 28 days. This observation is often found in the literature [26], where a delayed strength development in LW concrete is reported. Finally, after 90 days of curing, the compressive strength of the mortars with 10% SCM, exhibited comparable values.

The results of the sorptivity test, S (mm/min$^{0.5}$), are illustrated in Figure 3. Comparing the sorptivity values for the NW and LW mortars, both they registered similar values, although LW-REF mortar exhibited slightly lower sorptivity. In general, most durability properties are governed by the characteristics of the cement paste and there are not affected by the aggregates types [34]. Thus, sorptivity it was expected to exhibit similar values, since the amount of the cement paste is approximately the same in both mortars.

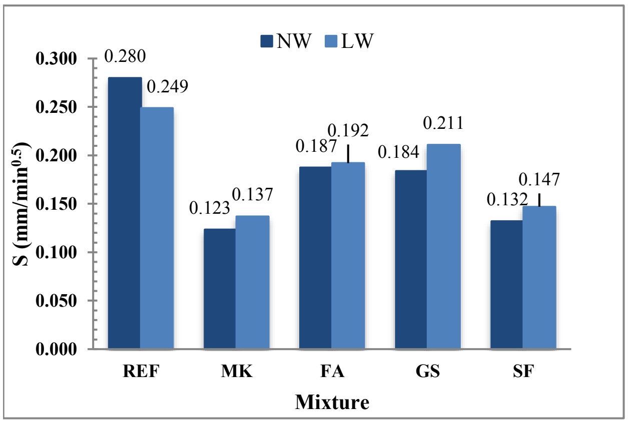

Fig.3. Sorptivity of NW and LW mortars, for samples aged 28 days.

Although this trend has been reverted after the SCM addition, sorptivity values remain almost unchanged. However, sorptivity has been decreased by the SCM addition and both types of LW or NW mortars with MK or SF performed the lower values, compared to their counterparts reference samples, as it is also reported in the literature [27], [26]. Although lightweight aggregate particles contain very large pores, these they are not continuous and it seems that they have been sealed up by a denser cement paste, enriched with the SCM pozzolanic products [26] [35].

Open porosity, OP (%) values are depicted in Figure 4, for both NW and LW mortars. As long as lightweight aggregates were used, it was expected that in mortars would be present a high volume of open pores [36][37]. Therefore the OP values of LW mortars are significantly higher than those of NW mortars. Moreover the SCM usage didn't manage to efficiently decrease the volume of the open pores of LW mortar as it has been made in the case of NW mortars where an approx. 35 % of decrease is registered. However, high values of porosity, doesn't necessarily means that high permeability of concrete or mortars should be expected [38]. As already mentioned [39], it is the cement paste that determines permeability parameters and the recorded improvement of OP came as a result of the addition of the different SCM. Once again MK mortars registered the best enhancement in both LW and NW samples. FA and GS NW mixtures, also exhibited improved OP, as it was expected according to the literature [40], but in the case of LW mortars their additions lead to similar to the reference mortars OP values.

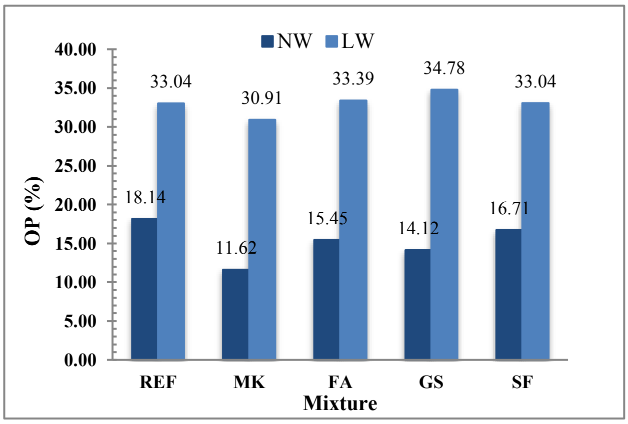

Fig.4. Open porosity of NW and LW mortars, for samples aged 28 days.

The results regarding the resistance to chloride penetration, as it is expressed by the chloride penetration coefficient, D_{nssm} ($\times 10^{-12}$, m^2/s) are depicted in Figure 5. LW mortars in general performed significantly lower values of D_{nssm}, compared to their counterparts NW mortars. The reference sample LW-REF performed approximately half value of D_{nssm}, while the LW mortars contained FA, GS and SF, they have been registered values even lower than the half of their counterparts NW mortar mixtures. These findings are in contrast to the expected behaviour of LW mortars due to the increased porosity of aggregates. However, lower permeability of LWA concrete and mortar compared to NW mixtures with similar w/c ratios is also found which it is attributed to the internal curing provided by the light weight pre-saturated aggregates and to the achievement of an improved transition zone [38][41][42], especially by the use of SCM [43].

Thus, regarding the effect of SCM addition on the chloride penetration coefficient, it has been shown that in both NW and LW mortars, the influence that the SCM addition had on the resistance to chloride penetration of the mortars was highly positive. Especially in the case of LW mortars the effect has been reported at the level of 79% ±5. These results are already published elsewhere [44] and similar reported results confirm the positive effect of SCM's especially when added to LW mortars and concrete [26][43].

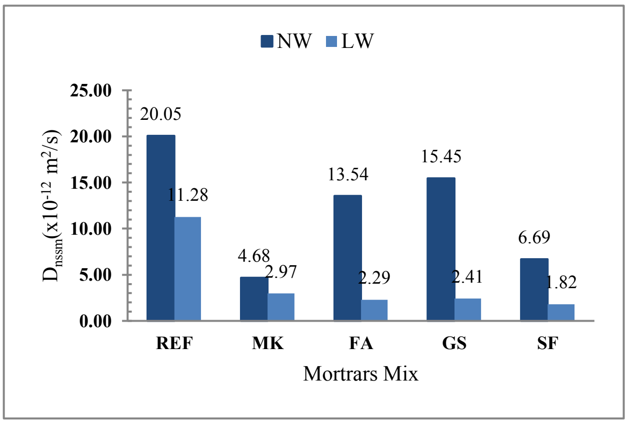

Fig.5. Chloride penetration coefficient, D_{nssm} ($\times 10^{-12}$ m^2/s) of NW and LW mortars, for samples aged 28 days.

Comparing the effect of each SCM, it has been shown that in both NW and LW mixtures MK addition had a very positive effect, while SF addition seems to work better in the case of LW mixtures. On the other hand, the additions of FA and GS, improved the chloride penetration resistance of NW mortars at a level of ~25%, while, as already mentioned, they found to significantly reduce the chloride penetration coefficient of LW mortars. It has to be considered that pastes in mortars with both FA and GS additions, due to their delayed pozzolanic activity, are more porous [43]. Recently, the efficiency of FA addition against the chloride penetration in terms of k-value, has been correlated with the chloride ingress (x_d), showing once again that the curing time increases K values, up to 40%, approximately [45]. Therefore any improvements in durability parameters such as chloride penetration resistance, is expected to occur at grater curing age.

By using the chloride concentration (w/w) found in each mortar sample, the chloride diffusion coefficient, D_e ($\times 10^{-12}$, m^2/s) was evaluated for all mortar mixtures and illustrated in Fig. 6. LW mortars exhibit considerably lower values of D_e, compared to their counterparts of NW mixtures, although they contain higher amount of cement paste, which is more vulnerable to the chlorides' diffusion than aggregates. Instead, lower amount of chlorides was found in LW mortars, resulted in D_e values up to 90% lower compared to their counterparts of NW samples

It seems that the tortuosity of the pores in the LW aggregates has a key role, as it entraps chlorides and restricts their kinesis [37].

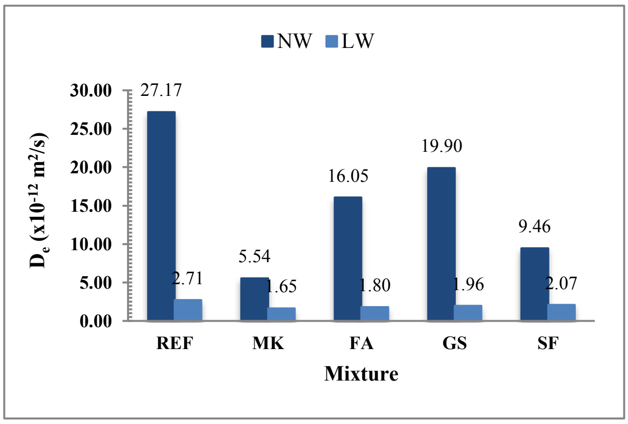

Fig.6. Chloride diffusion coefficient, D_e ($\times 10^{-12}$ m^2/s) of NW and LW mortars, for samples aged 28 days.

As far as the effect of the SCM addition on the chloride diffusion coefficient of the mortars is concerned, it is clearly shown in Figure 6, that their effect is extensively beneficial in the case of both NW and LW mortars. MK again had the higher impact on mortars and a reduction up to 80 % is reported in the case of MK addition. SF addition also benefits the resistance of the mortars to a significant extent. The reported in LW mortars reduction occurs to a lower extent compared to the NW mortars. Better performance of LW concrete compared to NW concrete both containing SF and GS against chlorides diffusion, is also reported in the literature [42] and it has been attributed to the internal curing provided from LW aggregates. Herein, in both types of mortars, MK and SF were the additions with the greater impact. In any case, the resistance to the chlorides diffusion of concrete containing any of these SCM, was impressively improved as it has been also reported in the literature [46].

4 Conclusion

The present study investigated the properties of fresh and hardened NW and LW mortars, contained five different SCM that replaced cement at 10%. The study of two types of mortars, blended with the different SCM, demonstrated the main comparative benefits of the LWA mortars and the improvements that they could support its wider usage in construction. Based on these strength and durability results of the current experimental work, it was concluded that the pumice lightweight mortars can be used in the construction as they fulfil the strength requirements and they exhibit extremely improved durability, especially against chloride ingress. More analytically, the main findings of the conducted work, were:

- Workability of LW mortars is affected by the characteristics of pumice sand and increased SP amount is needed. Mortars with SF and MK, demanded even higher SP dosage. In any case, the workability of the mortars is effectively controlled using relatively low SP dosage.
- LW mortars achieved satisfactory strength and they could be used as masonry mortars. The addition of MK showed the higher positive influence in strength compared to other SCM. It must be noticed that in the case of the LW mortars, significant increase on compressive strength due to the SCM usage, is evident after 28 days of curing.
- Sorptivity values of LW aggregates were reported similar to NW mortars and were marginally decreased when MK or SF were added. On the other hand, open porosity was reported higher in the case of LW mortars. The SCM addition didn't manage to improve the open porosity values in the case of LW mortars, although MK addition had the best positive effect in both types of mortars.

- LW mortars exhibited better resistance to chloride ingress than NW mortars. However, in both types of mortar, the influence that the SCM addition had on their resistance to chloride ingress was high, especially in the case of LW mortars. MK and SF exhibited similar impact, although SF performed slightly better in LW mortars.
- Lower amount of chlorides was found in LW mortars, resulted in diffusion coefficient values up to 90% lower compared to their counterparts of NW samples. It seems that the tortuosity of the pores entraps chlorides and restricts their kinesis. In both types of mortars, MK and SF were the additions with the greater impact.

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