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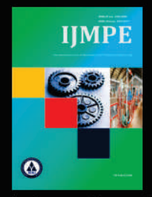

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EDITORIAL

It is my proud privilege to welcome you all to the ISER International Conference at Helsinki, Finland. I am happy to see the papers from all part of the world and some of the best paper published in this proceedings. This proceeding brings out the various Research papers from diverse areas of Science, Engineering, Technology and Management. This platform is intended to provide a platform for researchers, educators and professionals to present their discoveries and innovative practice and to explore future trends and applications in the field Science and Engineering. However, this conference will also provide a forum for dissemination of knowledge on both theoretical and applied research on the above said area with an ultimate aim to bridge the gap between these coherent disciplines of knowledge. Thus the forum accelerates the trend of development of technology for next generation. Our goal is to make the Conference proceedings useful and interesting to audiences involved in research in these areas, as well as to those involved in design, implementation and operation, to achieve the goal.

I once again give thanks to the Institute of Research and Journals, The IIER for organizing this event in Helsinki, Finland. I am sure the contributions by the authors shall add value to the research community. I also thank all the International Advisory members and Reviewers for making this event a Successful one.

Editor-In-Chief
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★★★

ALKALI-ACTIVATED MORTARS FOR SUSTAINABLE CONSTRUCTION MATERIAL: EFFECTS OF BINDER-TO-AGGREGATE RATIO AND CURING CONDITIONS

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Abstract - Valorisation and reuse of industrial wastes has become a worldwide compelling topic to improve the sustainability of processes and materials. This paper discusses an alternative way to recycle the biomass fly ash, generated by the kraft pulp industry, to manufacture novel geopolymeric mortars intended for applications in construction. Biomass fly ash was used as a raw material, in partial substitution of the commonly used metakaolin, natural siliceous sand as aggregate. The followed manufacture process is highly simple and reproducible. Various proportions binder to aggregate were tested to study the effect on the final mortars properties. The mortars mechanical resistance was also studied in relation to the temperature and duration of curing in order to define the best condition to gain the maximum mechanical resistance. Also submersed curing was tested. Moreover, the mechanical performance was investigated under the effect of natural ageing. The investigations indicate that the novel mortars can be used as structural material in construction and represent an efficient solution to reduce the environmental footprint associated with waste disposal in light of the circular economy.

Keywords - Construction, Mortar, Geopolymer, Biomass fly ash, Pulp-paper industry, Waste, Circular economy.

I. INTRODUCTION

In the last XX century, many concerns started to arise on environmental and socio-economic issues such as depletion of natural resources, climate change, and atmospheric pollution. Then, both the public and private sectors, pushed over by a pressing public opinion, started to discuss on the most convenient way to improve the worldwide industrial development in a sustainable and effective way.

The circular economy is intended as the most accredited economic model addressing the issues of environmental depletion and long-term economic growth and stability, strictly coupled with social equity. In accordance, the circular industrial management, from manufacture to disposal, has started to be considered a viable and cost-effective solution to improve the industrial systems. Valorisation, reuse, and recycle of trashes, wastes, by-products, and end-of-cycle products have then become a real and increasing business [1, 2].

Transforming wastes into novel and useful products is becoming highly important. Indeed, many economic sectors, as construction, are facing the expanding problem of wastes and by-products treatment and disposal, that yearly generates an incredible loss of financial resources. Then, new technologies are investigated to transform low-quality, zero- or low-cost materials into high-value products with a surplus of financial resources and a consequent reduction in environmental impact associated with human activities.

This paper investigates the production of green geopolymeric (GP) mortars, formulated with industrial waste, and mainly intended for applications in civil engineering and architecture. GP are inorganic alkali-activated binders made of a reactive solid alumina-silicate source interacting with an alkaline solution [3]. Nowadays, GP are considered the most viable and green alternative to the Ordinary Portland Cement [4, 5].

In this work, the common source of aluminium and silicon, metakaolin (MK), was partially substituted by biomass fly ash (BFA), making the GP more sustainable. The used BFA derives from a local Kraft paper-pulp industry. The Kraft process involves the digestion of lignin by an alkaline mixture of sodium hydroxide, sodium sulfide, and water [6]. During such process, the BFA is produced in the biomass boiler employed for energy production at mill site and collected at the electrostatic precipitator as waste [7]. Here, the BFA is recycled and used to substitute the MK with a rate of 70 wt.%, generating a high environmental drawback [8, 9].

This work details the effects of binder-to-aggregate ratio (mix design), various curing conditions (temperature, duration, and medium), and natural ageing to study the long-term performance and durability of the studied GP-mortars. Moreover, it offers a valid alternative to traditional disposal suggesting a methodology to manufacture a new class of novel green construction materials intended for a global market.

II. EXPERIMENTAL DETAILS

2.1. Raw materials

In this work the GP-binder was designed with the following oxides ratios: SiO_2/Al_2O_3 = 5.27, Na_2O/Al_2O_3 = 1.31, Na_2O/SiO_2 = 0.25, and H_2O/Na_2O = 15.9, according to [8].

The tested formulation uses a mixture of BFA (70

wt.%) and MK (30 wt.%) as a solid source of alumina and silica. Benchmark MK is purchased as Argical™ from Univar® and used to adjust the GP desired molar oxide ratios. BFA was supplied by a local Kraft pulp industry and presents α–quartz, calcite, mica group mineral (mixture of muscovite/illite), and microcline as main crystalline phases.

The alkaline activation was achieved by using a solution of sodium silicate (H_2O = 62.1 wt.%; SiO_2/Na_2O = 3.15; Quimialmel, D40-PQ) and sodium hydroxide (ACS reagent, 97%; Honeywell). The NaOH solution (10 M) was prepared by dissolving the sodium hydroxide pellets in distilled water at least 24 h prior to use. The used molarity was selected based on the cited previous work.

The natural siliceous sand used as fine aggregate was furnished by Saint-Gobain Weber Portugal.

The main characteristics of the produced GP-binder are: ratio water/cement - 0.78; bulk density - 1307 Kg/m^3; sorptivity by immersion – 38 %; coefficient of capillarity - 0.87 kg/(m^2·min$^{0.5}$); uniaxial compressive strength - 22.15 ± 1.22 MPa.

2.2. Manufacture process

GP-mortar specimens were prepared according to EN 998-2:2016, adapting the common procedure used for traditional cement-based mortars.

Mortar manufacture consisted of [9]: (I) dry mixing of MK and BFA to ensure a uniform blend for 1 min; (II) homogenisation of sodium hydroxide and silicate at 50 rpm for 5 min; (III) mixing of the alkaline solution with the solid precursors at 60 rpm for 9 min; (IV) adding the sand and mixing for 1 min to ensure homogeneity. The fresh slurry was poured into standard metallic moulds (40×40×160 mm) and vibrated for 2 min on a vibrating table to achieve compactness, and remove entrained air. Then, the moulds were sealed with a plastic film for 24 hr to prevent water evaporation until the specimens were hardened. Finally, the moulds were unsealed, the specimens demoulded and cured until testing.

2.3. Materials characterisation

The consistency (spread) of the fresh GP-mortars was estimated by flow table testing according to EN 1015-3:1999. Bulk density (geometrical) was calculated as the average of three specimens. The water absorption was determined by the Archimedes principle (weight variation, ΔP/P, %); the capillary coefficient (C) according to EN 1015-18. Three replicas were used to calculate the mean values for the two sorptivity tests. The mechanical performance was determined according to EN 1015-11 and EN 998-2 by means of the uniaxial compressive strength (UCS) test. A universal testing machine (Shimadzu, AG-25TA), provided with a 250 kN load cell, running at 0.5 mm/min displacement rate, was used. The software that returned the measured load and strain values was Trapezium v. 1.2.4. The mean values were obtained from three tests randomly taken from the sample batch. Axial strain (ε) was also calculated as specimens height variation (ΔL/L, %).

2.4. Mortars mix design and curing conditions

This scientific study is formally divided in various steps to evaluate the most efficient mix design and the most effective curing conditions.

Step – 1: Mortars were produced by adding the aggregate (sand) in five proportions, binder/aggregate ratio (B/A), in order to evaluate the influence on the GP-mortars final properties. The tested GP-mortar formulations (mix design) are shown in Table 1. Here the liquid/solid (L/S) ratio and the measured consistency (flow table test) are also reported. The five formulations were cured at ambient conditions (20 °C, 65% RH) and tested at the 28th day of curing. This procedure avoids any supply of external heat and, consequently, generates a more sustainable and cost effective process. This task will allow to define the best mix design intended for applications in construction.

Specimen	Ratio		Spread [cm]
	B/A	L/S	
1	1:1	0.391	>30
2	1:2	0.261	26
3	1:3	0.196	21
4	1:4	0.156	15
5	1:5	0.130	10

Table 1: Mortars mix design

The most suitable mix design (that resulted the one with ratio B/A equal to 1:3) was then used for the following steps. Those foresee the curing at different temperatures and durations to understand if (and eventually how) temperature and duration of curing influence the final mechanical resistance (UCS).

Step – 2: Specimens were cured at different temperatures, following two procedures: (I) curing at constant temperature in a climatic chamber for 28 days; (II) curing at constant temperature in a climatic chamber for the first day; then at ambient conditions (20°C) for 27 days. The curing humidity (RH) has been kept constant at 65% (ambient humidity).

Step – 3: Specimens were cured, from the first moment, into water (distilled and salty), to simulate possible applications for submersed structures.

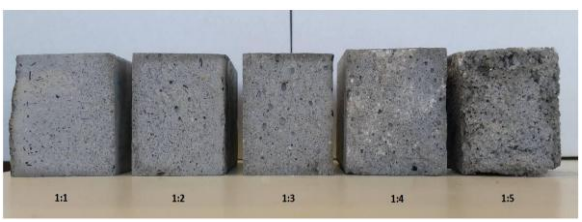

Fig. 1. Cross sections views of the produced GP-mortars.

III. RESULTS AND DISCUSSION

3.1. Step – 1: varying the ratio B/A

The consistency of the fresh GP-mortars gives an indication of the materials workability and its real possible application. The suboptimal consistency strictly depends on the intended specific application. In any case, a too pasty (< 15 cm) or, on the contrary, a too fluid (> 25 cm) slurry may generate voids within the matrix, aggregate segregation, and delay in setting and curing – with subsequent issues on matrix uniformity and on the overall performance. In this study, considering the expected application in construction, a consistency ranging between 18–22 cm guarantees a good material workability with suitable compaction and homogeneity [10]. However, it must be recalled that consistency can be modified by adding specific chemicals (i.e., plasticisers), but their use is avoided in this study to prevent any undesired effects. The mortars measured consistencies (spread) are reported in Table 1. It is observed that decreasing the L/S ratio, that is to say increasing the amount of the admixed aggregate, mortars become more pasty and, consequently, their workability decreases. As a direct consequence, larger voids are formed as shown in Figure 1. Only the specimen n. 3 (ratio B/A - 1:3) presents a suboptimal consistency (21 cm).

The bulk density of the 28 days hardened GP-mortars resulted: GP – 1307 Kg/m^3; mortar ratio 1:1 - 1440 Kg/m^3; mortar 1:2 - 1771 Kg/m^3; mortar 1:3 – 1832 Kg/m^3; mortar 1:4 - 1921 Kg/m^3; mortar 1:5 - 1765 Kg/m^3. GP-binder is reported for comparison. It is observed that the bulk density increases with the relative amount of aggregates. However, the formulation n. 5 (ratio B/A - 1:5) shows an anomalous behaviour that is caused by its very poor workability, which does not allow a good compactness. That is also evident from Figure 1.

Water sorptivity was evaluated by immersion and by capillary action (coefficient of capillary). The calculated values are shown in Figure 2 A and B, respectively. The GP-binder water absorption by immersion resulted equal to 38%. This high value is due to a large number of small pores that are present in the gel, as reported in [9]. In the GP-mortars, the porosity is filled up by the aggregate leading to smaller values. This effect is proportional to the amount of sand. In general, the reported values are suitable for applications in construction. The same observations may be reported for the capillarity absorption. Again, the value shown by the GP-binder resulted higher than the mortars' due to the number of small and interconnected pores through the binder gel. This activates the water uprising action and, hence, a higher capillarity. On the contrary, the sand of the mortars fills up the pores, then preventing the water to rise. Consequently, smaller values are observed. Again, the sample n. 5 shows an anomalous behaviour due to the presence of the large voids. According to the physical structure of the various mortars, and depending on the quantity of binder in the matrix, the coefficient C tends to diminish.

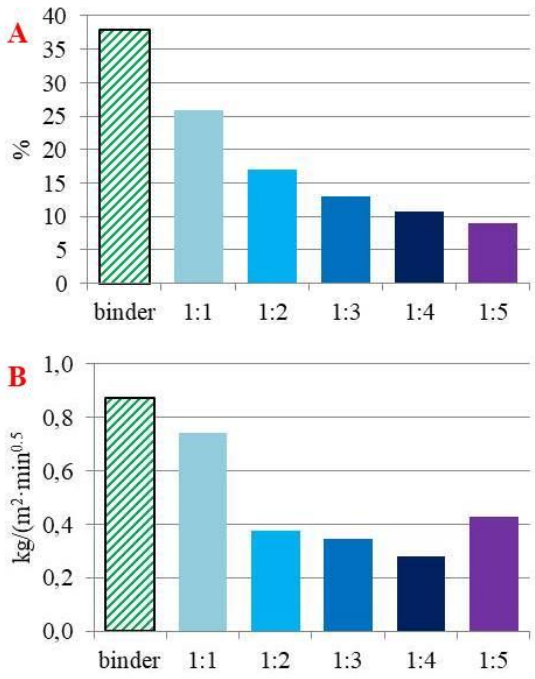

Fig. 2. Water sorptivity by immersion (A) and by capillary action – coef. of capillary (B).

Generally speaking, the mortars for masonry applications must show a compressive strength ≥ 10 MPa (class of resistance M10, or higher) in order to be suitable for structural applications in construction. For each tested formulation, uniaxial compressive strength (UCS) and bending resistance (BR) were assessed at 28 days of curing. Deflection and strain (at rupture) were also calculated.

Figure 3 shows the calculated values: BR (A), UCS (B), relative deflection (C), and strain (D). It is observed that the BR of GP-mortars ns. 2, 3, and 4 resulted higher than the one of the binder. Indeed, the addition of sand improves the resistance to deformation. Mortar n. 5 showed a value close to the binder; the same could be observed for specimen n. 1 considering the calculated standard deviation. In detail, the calculated BR values resulted: binder - 3.05±0.37 MPa; ratio 1:1 – 2.45±0.49 MPa; ratio 1:2 – 4.69±0.33 MPa; ratio 1:3 – 4.08±0.58 MPa; ratio 1:4 – 4.03±0.52 MPa; and ratio 1:5 – 3.09±0.26 MPa. As a general trend, having reached the maximum value for the specimen n. 2, the BR tends to decrease by enhancing the aggregate amount. On the contrary, the respective deflections increase, meaning that using larger amount of aggregate makes the material more deformable and less brittle. According to the technology of construction, and for applications in civil engineering and architecture, that is not necessarily a positive factor since a high stiffness is required for all the inflexed horizontal elements, such as beams or slabs. Furthermore, deflections should be

minimized for aesthetic reasons. The compressive strength (expressed as UCS) is the key factor for evaluating a possible masonry application. It is observed that all the produced GP-mortars are suitable for structural applications in construction, generally showing UCS ≥ 10 MPa. Mortar n. 3 presented the highest value. Mortars n. 1 and 2 show similar values. Here, it seems that the aggregate contribution to compression strength is small, so the overall resistance is entrusted to the binder (that is present in higher quantities). By comparing the GP-binder with mortars n. 1 and 2, a constant reduction is observed, which is caused by the decreasing content of binder in the mixes. Mortars n. 4 and 5 show a UCS drop. This is particularly evident for the highest sand content (1:5). In detail, the calculated UCS values were: binder - 22.15±1.22 MPa; ratio 1:1 – 20.77±0.91 MPa; ratio 1:2 – 20.32±0.71 MPa; ratio 1:3 – 21.66±0.03 MPa; ratio 1:4 – 17.75±0.95 MPa; and ratio 1:5 – 14.54±0.93 MPa. According to UNI-EN-998-2, formulated GP-mortars n. 1, 2, and 3 are classifiable as M20; GP-mortar n. 4 as M15; GP-mortar n. 5 as M10. Calculated strains demonstrate that the addition of sand improves the stiffness of the material. Calculated values range between 1.7% and 2.2%.

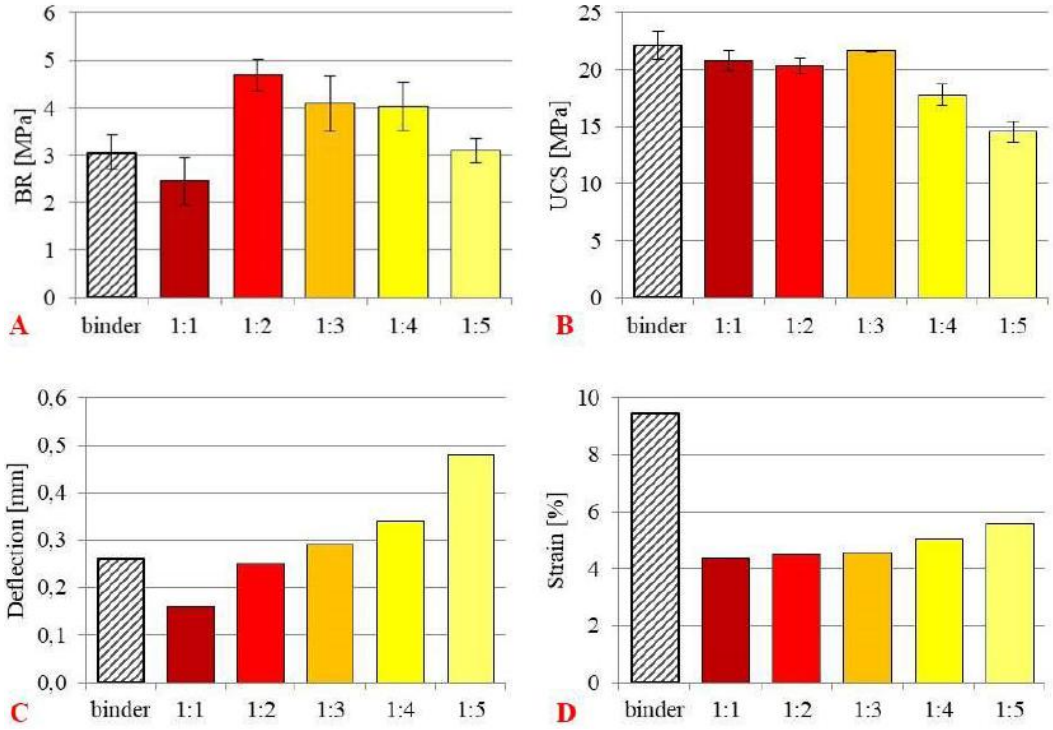

Fig.3. Mechanical performance: BR (A), UCS (B), deflection (C), and strain (D).

3.2. Step – 2: curing at various temperature

This step has been designed in order to understand which is the most effective curing temperature, and the corresponding duration. In accordance to EN 1015-11 and EN 998-2 (standards for masonry mortars) the mortars characteristic UCS was assessed at the 28th day of curing. UCS tests were also performed at the 1st and 7th days of curing in order to evaluate the progression of strengthening. Geopolymerization is a complex process that involves many chemical reactions to form a stable and uniform gel [11, 12]. These reactions usually start immediately after having mixed the alumino-silicate source (solid raw materials, in this case 70 wt.% of BFA and 30 wt.% of MK) with the alkaline activator. After the 1st day of curing, the most of the reactions have all occurred. Such reactions are highly exothermic, then a certain amount of heat is realised depending on precursors and curing conditions. According to the vast scientific literature on the topic, fresh GP are often placed at high temperature, usually 40°C or higher, to gain an early mechanical strength. That is commonly performed for a few hours up to one day.

During the previous step, the mortar n. 3 (ratio B/A - 1:3) has shown the best features for applications in construction due to its high mechanical resistance, suitable workability, and low water sorptivity. Moreover, the curing process was completely performed at ambient conditions (20 °C, 65% RH).

This specimen was then cured in distinct conditions to investigate the variabilities connected to mechanical peformance. In the first case (I) specimens were placed inside a climatic chamber where the temperature has been kept constant for the entire curing period (28 days). Temperature was set between -20°C and 100°C, with a 20°C step. This procedure envisages any possible real application (at a specific latitude / location) where a constant climatic condition occurs. Highly northern/southern

hemispheres, high altitude, or desert environments are some examples. In the second case (II) specimens were placed inside the climatic chamber at constant temperature for 24 hours (one day) only. Temperature ranged from 20°C to 80°C, with a 20°C step. Afterwards, samples were cured at ambient conditions (20°C) for the other 27 days. This procedure aims at understanding if providing an initial thermal energy boosts the GP-activation granting an early/final higher resistance. Technological elements or specific applications where heat may be furnished are here envisaged.

In both the cases, the relative humidity has been kept constant at 65%, (average ambient/laboratory conditions). Results are shown in Figure 4.

Temperatures ranging 20-100°C were kept in a climatic chamber Fitoclima 300 EP10 (serie 1762) by Aralab. Lower temperatures were reached into an ordinary refrigerator equipped with temperature and humidity sensors.

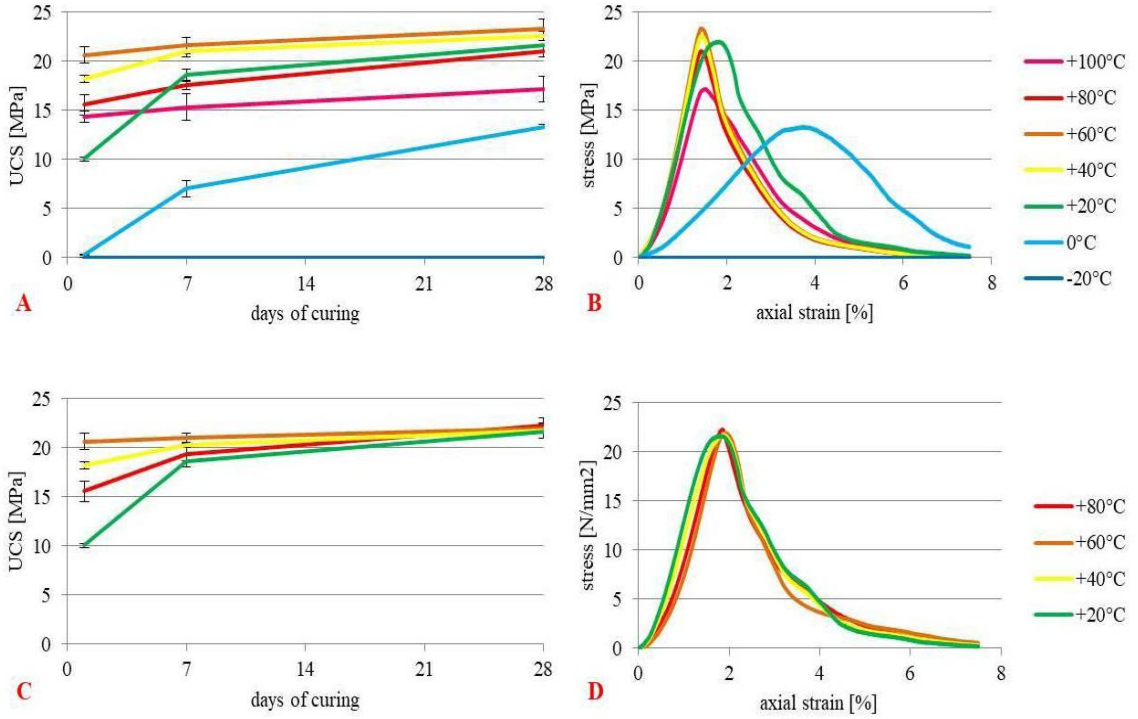

Fig.4. Mortar 1:3 mechanical performance. Curing in climatic chamber for 28 days: UCS vs. days of curing (A), stress-strain curves (B). Curing in climatic chamber for the first day only: UCS vs. days of curing (C), stress-strain curves (D).

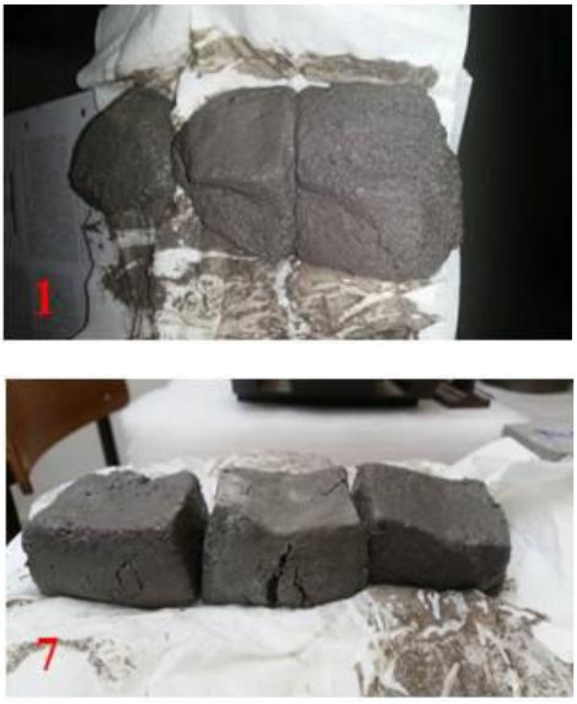

Fig.5. Specimens cured at -20°C that did not harden. From top: 1, 7, and 28 days of curing.

Figure 4 A-B and C-D shows the results of the case (I) and (II), respectively.

As a preliminary observation, for both the cases, for a temperature ranging between 20-80°C the final UCS tends to be comparable for all the specimens. That is particularly evident for the case (II). The main differences are observed at the 1st day of curing. An interesting fact is that GP-mortars cannot be cured at icy conditions (T < 0°C) (Figure 4 A) as defrosting the material, it simply melts (Figure 5). That was

expectable as the immobilised (iced) water prevents the GP-reactions to occur. The immediate consequence is that the considered mortar cannot be produced and cured in extremely cold (freezing) environments. At 0°C the mortar do not show any resistance after 1 day of curing. After 7 days a moderate UCS is observed. Then, some time is needed for the material to harden and gain strength as the remaining reactions keep going on. The 28-cured sample shows a UCS equal to 13.35±0.19 MPa, making the mortar classifiable M10, then suitable for masonry applications. Increasing the temperature to 20°C, up to 60°C, the material shows an increasing early strength gain (UCS test at 1 day of curing); then the deviation diminishes resulting a final 28-day UCS > 20 MPa for the mentioned curing conditions. To summarise, the 28-day UCS values are: 20°C – 21.66±0.03 MPa; 40°C – 22.59±0.43 MPa; 60°C – 23.37±0.93 MPa. In any case, the three different (constant) temperatures lead to class M20. No beneficial effects are observed by increasing further the temperature. Indeed, at 80°C the UCS values are generally lower, with a final 28-day UCS comparable to the other curing conditions (21.04±0.53 MPa / class M20). Temperatures ≥ 100°C are detrimental for the overall performance, downgrading the material to class M15. The relative stress-strain curves at 28-days curing are shown in Figure 4 B. It is observed that increasing the curing temperature (constant for the whole curing period) the material becomes less deformable (that is also in accordance to the general curing process [9]). Anyway, the values are comparable with an average deformation of 1.5±0.17 %. On the contrary, the mortar cured at 0°C shows a strain of about 3.6%.

In the second case (Figure 4 C-D) specimens were kept into the climatic chamber for 24 hours only, where the temperature ranged from 20°C to 80°C, with a 20°C step. Subsequently, the curing process was completed (up to the 28th day) at ambient conditions (20°C). As previously discussed, the measured 1-day UCS is identical to the first test, being the specimens tested at the same stage of curing that occurred at the same conditions (Figure 4 C). It is noteworthy that only after 7 days of curing, the 20°C mortar has mainly overcome the gap with the other specimens and after 28 days of curing the measured UCS values of all the 4 specimens are almost identical. Measured values were: 20°C – 21.66±0.03 MPa; 40°C – 21.77±0.76 MPa; 60°C – 22.29±0.47 MPa; 80°C – 22.29±0.73 MPa. All the mortars resulted class M20. From the analysis of the 28-day stress-strain curves (Figure 4 D), it can also be noted that the performance of the specimens is approximately the same. This observation reveals that providing heat during the first day of curing has no influence on the final mechanical performance, in terms of both UCS and deformation.

It is important to remark that all the four tested initial curing temperatures (applied for 24 hr only) lead to a similar final UCS. Consequently, considering the energy required to heat the specimens, along with the associated pollution, it can be concluded that this material can be efficiently cured completely at room temperature. That will contribute to a cost-efficient and sustainable manufacturing. The same observation could be made comparing the overall results. Indeed, mortars cured at the various temperatures (20-80°C) are all classifiable as M20, independently of the duration of the heat application.

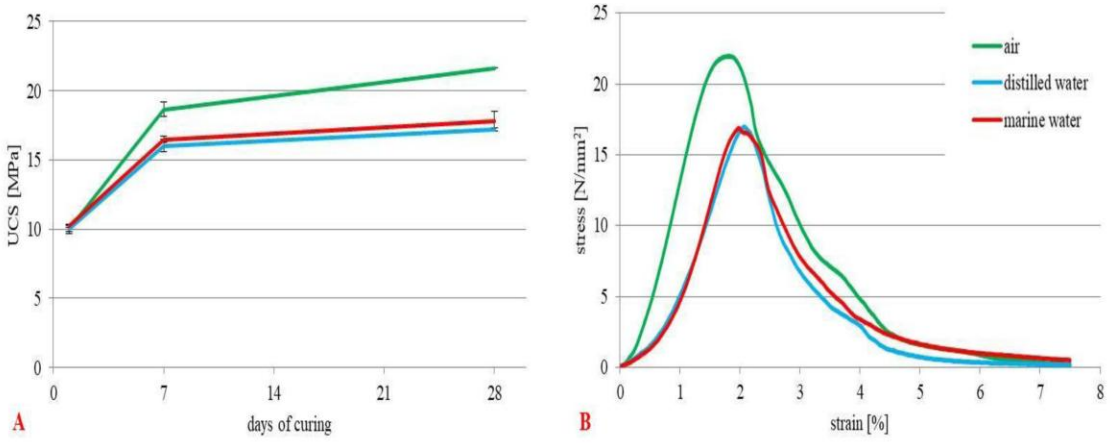

Fig.6. A: UCS values of the specimen cured in the three different means; B: stress-strain curves at 28-days of curing.

3.3. Step – 3: curing in water

This step has been designed in order to understand if the hardening and curing processes can occur submersed into water. That is aimed at investigating the possibility to use the studied GP-mortars for submersed structures and infrastructures such as bridges, piers, pipelines, etc.. Indeed, despite an optimal architectural and structural design, frequently the material degradation may lead to a quite short service life, if adequate technological solutions are not foreseen. Then, also protective layers or coating may be considered as possible real applications. Moreover, some particular building parts (i.e. foundations, poles, etc.) may be subjected to

particular harsh situations, such as proximity to water sources or presence of clay terrain.

For this purpose, two different typologies of water have been used: distilled and salty water. The first one is aimed at testing the manufacture feasibility, the second one at simulating the salt attack of the sea. Consequently, a solution of 40‰ NaCl in distilled water was prepared. The used salinity has been selected according to the average worldwide sea salinity. The results of the UCS tests on the sample (formulation B/A = 1:3) are shown in figure 6. The mechanical behaviour of the reference mortar cured in air is shown for comparative reasons.

First of all, it must be noted that the GP-mortar hardens and cures submersed into water. Indeed, the GP is a hydraulic binder and behaves in analogy to the traditional construction materials, as the cement does. It is observed that the UCS values of the two submersed materials are equal but lower to the one of the material cured in air. Accordingly, the calculated UCS values at 28-days of submersed curing resulted: curing in air (reference) – 21.66±0.03 MPa; curing in distilled water – 17.22±013 MPa; curing in salty water - 17.80±0.71 MPa. From figure 6B it is observed that the mechanical behaviour is independent from the nature of water and that the submersed-cured GP-mortars are more deformable (~ 5.20 % strain).

3.4. Effects caused by natural ageing

In this section we will focus on the effects caused by natural aging. Understanding how the physical features might change over time, is essential to indicate a suboptimal real application. That is crucial for the mechanical performance whose evolution could prevent a novel material from particular usages or may suggest more advisable applications. Furthermore, analysing such an evolution is essential to predict durability.

Traditional mortars (whether cementitious, lime-based, or others) usually harden and cure in presence of water gaining strength over time. This natural process can last years and usually generates hydrates. Furthermore, during the hydration reaction the material can show a significant reduction in pore volume, caused by the natural evaporation of water along with its chemical consumption, and the mineralogical species transformation. Those factors usually result into a great volumetric shrinkage [13, 14]. In GP-technology, also the GP-process occurs during hardening and curing but it does not form any hydrates. Consequently, the matrix structure, along with the pore size distribution, is refined throughout the hardening process [15, 16]. That is essential to understand the evolution of the mechanical performance, or of other properties as, i.e., the water absorption.

Figure 7 shows the mechanical performance during aging. Figure 7A shows the UCS value that is observed to increase over time. Figure 7B shows the UCS improvement rate. Day 0 represents the production date; day 1 when specimens were demoulded. At this stage the material shows a break point of 10.05±0.23 MPa, already assuring the M10 classification. During the first 7 days there is a gain of 86% in CS values but then the rate slows down. At 28 days, as discussed, the break point is 21.66±0.03 MPa; at 60 days it is increased to 24.97±0.80 MPa, corresponding to a total improvement of ≈150%. After 120 days of curing a UCS of 27.39±1.82 MPa, with an improvement of ≈172%.

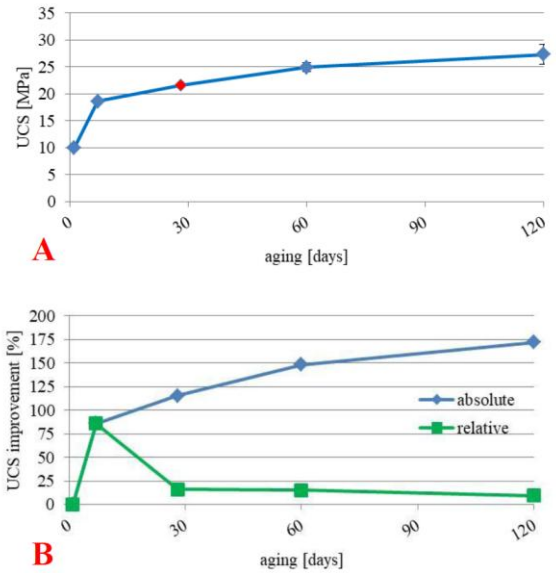

Fig.7. A: Mortar 1:3 mechanical performance. A - UCS vs. curing days (the red mark is the characteristic 28-day value); B - compressive strength improvement % (absolute and relative).

IV. CONCLUSIONS

This paper describes the development of GP- mortars intended for applications in construction, using BFA as binder major solid component and sand as thin aggregate. Five formulations, prepared with distinct binder/aggregate ratios, were tested. The curing temperature, duration, and medium were varied to evaluate the best conditions for a high mechanical resistance. The major conclusions are:

1. All the formulated mortars are suitable for structural applications in construction, being classifiable at least as class M10.
2. Increasing the amount of the aggregate the slurry becomes less workable, showing a decreasing consistency, the bulk density increases, and the water sorptivity, either by immersion and by capillary action, decreases.
3. The optimal binder/aggregate ratio resulted 1:3 with a 28-day bending resistance equal to 4.08±0.58 MPa, and a uniaxial compressive strength equal to 21.66±0.03 MPa (class M20).
4. An initial higher curing temperature assures high initial strength (1-day curing); however the 28-days UCS are comparable.

5. Curing the specimens at ambient conditions, without providing any external source of energy, contributes in saving electricity, lowering the manufacture costs and the CO2 emissions.
6. GP-mortar hardens submersed in water, independently of the presence of possible salts, and presents a lower UCS compared to traditional curing in air.
7. The GP-mortar keep on gaining strength during natural ageing (curing).

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