Advances in Concrete Construction, *Vol. 6, No. 3 (2018) 285-296*
DOI: https://doi.org/10.12989/acc.2018.6.3.285

Behaviour of self compacting repair mortars based on natural pozzolana in hot climate

A. Benyahia* and M. Ghrici[a]

Geomaterials Laboratory, Civil Engineering Department, Hassiba Benbouali University of Chlef, P.O. Box 151, Chlef 02000, Algeria

(Received December 18, 2017, Revised April 1, 2018, Accepted April 17, 2018)

Abstract. In the present paper, the results of an experimental study of the bond between repair materials and mortar substrate subjected to hot climate is presented. Half-prisms of size 40×40×80 mm, serving as a substrate mortar samples (SUBM) were manufactured in the laboratory and then stored at an ambient temperature for 6 months. Five self compacting mortar mixes (SCMs) incorporating 0%, 10%, 20%, 30%, and 40% of natural pozzolana as white cement replacement were used as repair materials. Repaired composite samples (SCMs/SUBM) were cured at hot climate for different lengths of time (28 and 56-days). During the first week of curing, the composite samples were watered twice a day. The test carried out to assess the bond between SCMs and SUBM was based on three-point bending (3 PB) test. The obtained results have proved that it was feasible to produce compatible repair materals in this curing environment by using up to 30% natural pozzolana as white cement replacement.

Keywords: self compacting mortar; natural pozzolana; substrate; hot climate; bond

1. Introduction

The town of Chlef which is located in the north of Algeria, is experiencing significant growth in term of reinforced concrete structures after the 1980 earthquake. As the durability of concrete structures is greatly compromised by the region environment, exposure of concrete structures in Chlef at temperatures up to 45°C and relative humidity ranging from 30 to 60% during a typical summer day would be the cause of severe cracks due to thermal and mechanical stresses thus reducing the serviceability of these structures (Neville 2000, Anisuddin and Khaleek 2005).

Mortar has become an increasingly attractive research area as it can serve as a basis for the properties of flowing concrete (Domone and Jin 1999) and can be used as repairing material to fill up the opening cracks in the concrete structures. Adding fibers in the mortar has numerous important effects on its precracking behavior. It mainly enhances its post-cracking response and gains in a more ductile material behavior (Felekoglu *et al.* 2007). However, Ferrara *et al.* (2007) have shown that using different types or volume of fibers in mortar mix can greatly affect its workability, which is the key factor to obtain successful fiber-reinforced mortar for repair

∗Corresponding author, Ph.D., E-mail: a.benyahia@univ-chlef.dz
[a]Professor, E-mail: m_ghrici@yahoo.fr

http://www.techno-press.org/?journal=acc&subpage=7 ISSN: 2287-5301 (Print), 2287-531X (Online)

applications (Kurder *et al.* 2007).

Within the past two decades, a highly fluid mortar called self-consolidating mortar (SCM) has caused dramatic changes in the concrete industry. Indeed, the latter does not require any external vibration and, by its own-weight can produce mortar with sufficient compaction and smooth surfaces with no honeycombing or voids (Ramli and Tabassi 2012, Silva and de Brito2015). Consequently, it can be used with wide spread application as concrete repair materials (Courard *et al.* 2002).

Several researchers have focused their research efforts in using gray Portland cement to manufacture SCM (Benyahia *et al.* 2017a, Venkatesh *et al.* 2017, Sredivi *et al.* 2017, Güneyisi and Gesoğlu 2008, Felekoğlu *et al.* 2007), but there are abilities for white cement formulations.

Self-compacting white mortar is a new cementitious product that has been used in rehabilitation and decoration and has improved aesthetic aspects. As in the case of SCM, mineral admixtures have also become an integral part of the design of the self-compacting white mortar. When used appropriately, they can improve the flow properties but also improve the strength and durability characteristics of this mortar (Lopez *et al*. 2009, Corinaldesi *et al*. 2012).

The addition of natural pozzolana in SCM mix due to the need to produce repair materials compatible with the existing concrete. Many researchers (Faria and Henriques 2002, Veiga *et al.* 2009) have reported that natural pozzolans can be used as binder for the production of repair mortars compatible to old authentic mortars.

The importance of adding pozzolans in concrete was mainly the increased durability, including sulfate resistance, control heat of hydration, and cost reduction (Rodriguez-Camacho and Uribe-Afifi 2002, Ghrici *et al*. 2006, Ghrici *et al*. 2007). Pavlidou (2012) tested two natural pozzolans available at the Greek market, from the view point of morphological, analytical physical and thermal. Their results revealed that the pozzolans tested, are materials of high quality and can be used for the production of compatible repair mortars.

Ezziane *et al.* (2007) found that the optimum natural pozzolana content was in range of 15% and 20% for 20°C and 60°C curing, respectively. This encourages the use of this material in hot climate without compromising resistance. Recently, Benyahia *et al*. (2017b) have formulatted a repair mortar mixture containing 20% natural pozzolana as cement replacement. The results of their study reveal that the product meets the requirements of class R4 mortar according to EN 1504-3 and satisfied the requirement of bond strength as per ASTM specifications.

The main goal of this research is to evaluate the feasibility of producing self-compacting white mortars using natural pozzolana. Five SCMs mix incorporating 0%, 10%, 20%, 30% and 40% natural pozzolana as white cement replacement were evaluated in the fresh (flowability) and hardened (flexural and compressive strength) states in comparison to a control mortar. Furthermore, the bond strength between the manufactured SCMs and parent mortar was tested at later age, under flexure by applying the third point loading (3PB) to evaluate their behavior at hot environment in view of failure modes.

2. Experimental

2.1 Material properties

White Portland cement referred as CEMI 52.5 was used in the present investigation. Cement characterization tests were conducted in accordance with EN 197-1(2000). Table 1 summarized the chemical composition and physical characteristics of cement.

The natural pozzolana (NP) used in this investigation had the appearance of crushed pumice, resulting from the eruption of the Bouhamidi volcano (Beni Saf, in north-west of Algeria). It was milled with a laboratory pulverizer to a particle-size distribution with a mean-particle diameter (d_{50}) of 125 μm. Table 1 also presents the chemical composition and physical properties of natural pozzolana.

Locally available river sand with 3 mm maximum size was used, having specific gravity and fineness modulus of 2.64 and 1.43, respectively. A new generation superplasticizer based on acrylic copolymer conforming EN 934-2 (2009) specifications, with a density of 1.06 and solid content of 30.2% was used in mortar mix (Table 3). Two types of fibers are incorporated in equal amounts in all mortar mixtures. The first polypropylene fiber (PPF) and the second, polyvinyl alcohol fiber (PVA). The general characteristics of these fibers are shown in Table 2.

Table 1 Physical physical and chemical properties of Portland cement and natural pozzolana

Property		White cement	Natural pozzolana
Physical properties	Initial setting time (minutes)	147	--
	Final setting time (minutes)	191	--
	Specific gravity	3.06	2.74
	Blaine specific surface area (m^2/kg)	420	510
	28-days compressive strength (MPa)	52.5	--
Chemical analysis, Percent by weight (%)	Silicon dioxide (S_iO_2)	21.28	53.71
	Aluminum oxide (Al_2O_3)	5.75	17.50
	Ferric oxyde (Fe_2O_3)	3.10	10.10
	Calcium oxide (CaO)	64.67	10.50
	Magnesium oxide (MgO)	1.40	2.20
	Sulfur trioxide (SO_3)	1.83	0.40
	Potassium oxide (K_2O)	0.75	0.50
	Sodium oxide (Na_2O)	0.12	0.80
	Calcium oxide (free)	0.5	--
	L.O.I	1.06	4.30

Table 2 General characteristics of polypropylene (PP) and polyvinyl alcohol (PVA) fibers.

Type of fiber	Photo	Length (mm)	Density (g/cm^3)	Melting point (°C)	Young modulus (GPa)	Elongation at break (%)	Section of fiber (μm)
PP		12	0.9	150	3	50	30
PVA		8	1.3	230	41	6.5	39

Table 3 Mixture proportions of repair mortar mixtures and substrate (kg/m^3).

Mortar	Cement	NP	Powder	Water	Sand	W/P	SP	Fibers	
SCM-00NP	680	00	680	272	1100	0.4	10.4	PP	PVA
SCM-10NP	612	68	680	272	1100	0.4	10.8	0.62	0.62
SCM-20NP	544	136	680	272	1100	0.4	11.4	0.62	0.62
SCM-30NP	476	204	680	272	1100	0.4	12.0	0.62	0.62
SCM-40NP	408	272	680	272	1100	0.4	12.4	0.62	0.62
Substrate Mortar (SUBM)	300	--	--	150	1780	0.5	--	--	--

2.2 Mixture procedures

In order to evaluate the effect of natural pozzolana on the properties of SCM, five repair mortar mixtures (SCM$_S$) containing 0%, 10%, 20%, 30% and 40% of natural pozzolana as partial white cement replacements were prepared (Table 3). The water-to-powder ratio (w/p) and the volume fraction of fibers (PP+PVA) were kept constant in all SCM$_S$ mixtures. Appropriate adjustments were conducted in the amount of superplasticizer (SP) in each mixture to obtain rheological properties as recommended by the European Federation of Nationalised Association Representing Concrete (EFNARC Guidelines 2005). The substrate mortar (SUBM) is an ordinary Portland cement mortar (OPC mortar) usually used in the construction. The mix proportion of the SUBM is also presented in Table 3.

The following procedures were used to mix the SCM$_S$ with a total mixing time of 5 minutes: 1) The sand, natural pozzolana and white cement were introduced into the mixer bowl with a capacity of 5 liters. 2) During mixing for 2.0 min, two thirds of the mixing water were added slowly. 3) The superplasticizer diluted in the remaining water was then added, and mixing was continued for additional 3.0 min. 4) During the mixing, the PP and PVA fibers were dispersed manually. 5) Upon the mixing terminal, the fresh tests were conducted.

2.3 Testing methods

The self-compactness properties of the five SCM mixtures are evaluated by a mini slump flow and mini V-funnel flow time tests according to the procedure recommended by the EFNARC (2005). Slump-flow is used to describe the ability of a fresh mix to flow of in unconfined conditions, by measuring the speed of the flow and the final spread under its own weight. This is one of the most used tests to evaluate the consistency of the SCC mortar. V-funnel flow time can be used to evaluate the flowability or viscosity of the produced repair mortars.

Compressive and flexural strengths of SCMs samples were measured according to EN 12190-6 (1999). Three prism specimens measuring 40×40×160 mm was prepared for both compressive and flexural strengths for each repair mortar, at the ages of 7 and 28-days of water curing. The reported results are the average of three flexural specimens and six compression tests.

The compressive and flexural strength of the SUBM was determined on 40×40×160 mm prism specimens at 28-days normal water curing in accordance with the EN 196-1(2006) as well as at a hot-humid environment.

The adhesion between repair materials (SCMs) and SUBM was characterized with three-point bending test according to ASTM C78 (2002). The composite specimens (SCWM/SUBM) used in the

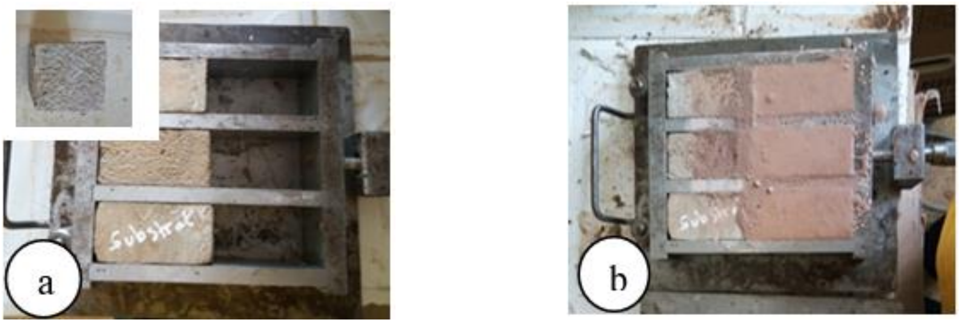

Fig. 1 Preparation of composite sample (a) Substrate specimens in moulds and (b) Casting of the repair material

Fig. 2 Prism samples curing in hot climate

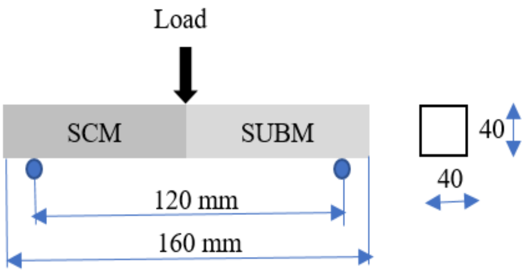

Fig. 3 Third-point's loading composite prism

three-point bending test consisted of two halves prism of dimensions 40×40×80 mm. One half cast with SCMs and bonded to a second half cast with the SUBM. The substrate part of the specimen was cast using metallic moulds and cured in water at 20±2℃ for 28-days. In order to ensure a good adhesion of the repair material, the surface of the substrate mortar (40×40) mm was treated by sandblasting then by brushing (Fig. 1(a)). Subsequently the substrate parts were stored for 6 months in an ambient laboratory temperature before casting the repair materials on top. The interfaces of the substrate samples were saturated in water for more than 6 hours and surface dried before casting the SCM. The repair mortars were cast on the top of the substrate (Fig. 1(a)) mortar specimens and then cured in hot climate (45°C and relative humidity ranging from 30 to 60%) (Fig. 2).

At the age of 28-days and 56-days, each composite is centered between the two plates of the apparatus and a load is performed at a constant speed of 0.5 kN/s until failure (Fig. 3). Moreover, the compatibility between the SCMs and the SUBM was evaluated according to the failure mode of the composite sample.

If the failure fracture occurs along the interface of repair material and substrate, then it is an incompatible failure (adhesive failure) or else (cohesive failure) the repair material is compatible with the substrate mortar (Ohama *et al*. 1986, Courard 1998).

3. Results and discussions

3.1 Mini-slump flow

The visual inspection of the five tested repair mortar mixtures showed no evidence of bleeding or segregation (Fig. 4). The measured slump flow for all repair mortars mix are summarized in Fig. 5. The measurements reported are the average of three tests. As can be seen in Fig. 5, that the obtained slump flow diameters were in ranges of 258 to 240 mm which satisfy the recommended value of EFNARC specifications (250±10 mm) for mortar.

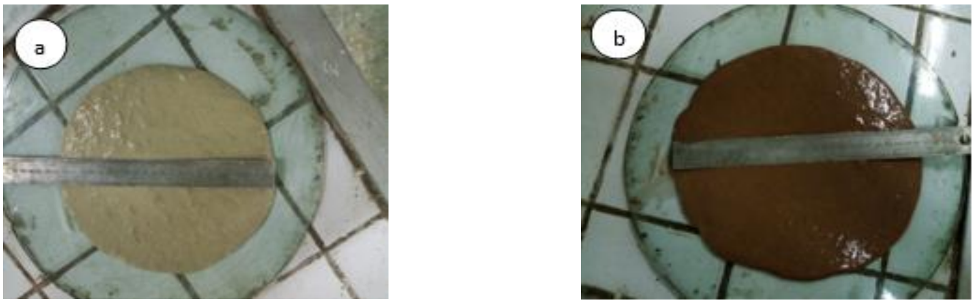

Fig. 4 Photographs of mortar slump flow: (a) SCM-00NP and (b) SCM-40NP

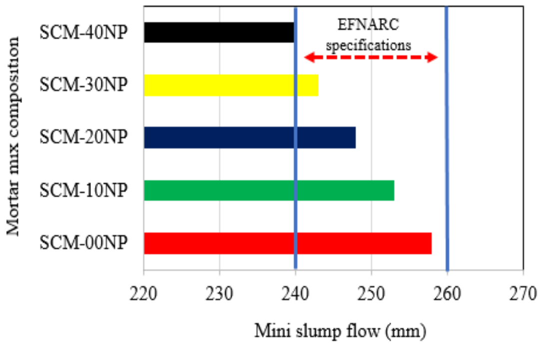

Fig. 5 Mini slump flow of the SCMs

The slump flow will decrease with increase in natural pozzolana content. Control mortar gave a slump flow value of 258 mm whereas mortars made with 10%, 20%, 30% and 40% natural pozzolana had respectively slump values of 258, 253, 248 and 240 mm.

As a percentage of natural pozzolana increased the mix become denser. For this reason, NP mixes require more amount of superplasticizer for achieving more flowability for self compacting mortars (see Table 3). These results corroborate those obtained by other researchers (Feng *et al.* 1990, Kaid *et al.* 2015)

3.2 Mini V-funnel flow time

Fig. 6 indicates that flow time of mortar increased with the increase in natural pozzolana content, indicating an increase in viscosity of the mixture (longer flow time). This is in agreement with a study performed by Sahmaran *et al.* (2006). Control repair mortar mix gave a mini V-funnel value of 7.2 s whereas mortars made with 10%, 20%, 30% and 40% NP achieved respectively flow time values of 7.8, 8.8, 9.5 and 10.5s. The observed values for all SCM mixtures that are lied

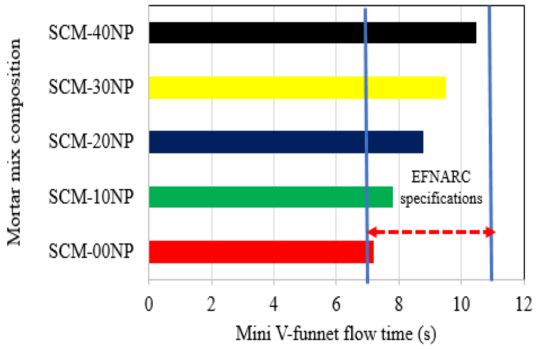

Fig. 6 Mini V-funnel flow time of the SCMs

down within EFNARC specifications (7 to 11 s).

3.3 Compressive and flexural strength

Results of compressive strength of the prisms prepared from the produced repair mortars and cured in water until the test dates (7, 28 and 56-days) are plotted in Fig. 7. It can be seen in this Figure; the compressive strength increases with age of mortar and decreases with increasing natural pozzolana content. The best strength was obtained for the control repair mortar mix (SCM-00NP) at all curing ages.

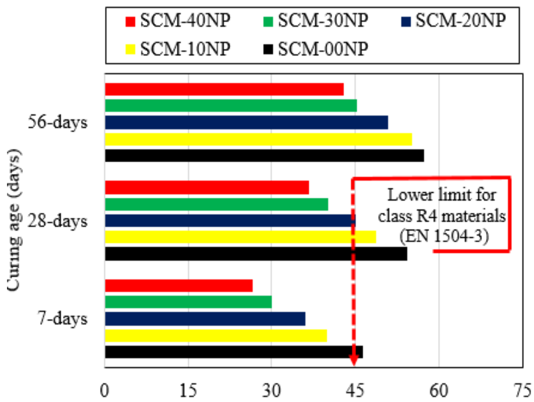

Fig. 7 Compressive strength of SCMs, at different curing time

The increase in strength of control mortar mixes may be attributed to the presence of high cement content. At 7-days curing, the réduction in the compressive strength values for the - SCM-10NP, SCM-20NP, SCM-30NP and SCM-40NP compared to the SCRM-00NP was about 14%, 22%, 35%, and 43% respectively. The strength reduction at this age can be explained by the fact that the hydration of natural pozzolana is slower than white cement.

When curing age was extended from 28 to 56-days, it can be seen that this strength difference will decrease. While in the case of SCM-00NP samples, this has been observed during first 28-days (8 MPa gain strength between 7 to 28-days and only 3 MPa between 28 to 56-days). For instance, the compressive strength of the mortar containing 10% NP and 40 NP% was found to be 10% and 32% respectively, lower than the control mortar at 28-days curing. However, this reduction was 4% and 24%, respectively for the same samples, at the age of 56-days. This could be attributed to the pozzolanic reaction. Which may lead to improve the aggregate paste bond through the densifcation of the transition zone and therefore formation of more secondary calcium silicate hydrate (C-S-H) gel. This confirms the results of previous works on the natural pozzolana (Haque and Kayali 1998, Liu and Xie 2005).

Based on the results plotted in Fig. 7, it seems possible to produce repair mortars class R4 according to the requirements of the European standard EN 1504-3 with a substitution rate of white cement by 10% or 20% natural pozzolana.

The flexural strength behaviour of the produced repair mortars SCM at various NP content and test ages is presented in Fig. 8. The flexural strength of the specimens is seen to increase with age. At early age (7-days), the reductions in flexural strength values of SCM-10NP, SCM-20NP, SCM-30NP and SCM-40NP compared to the SCM-00NP were, 17%, 25%, 32% and 39%. However, the rate of decrease diminished with the increasing age of curing (28 and 56-days).

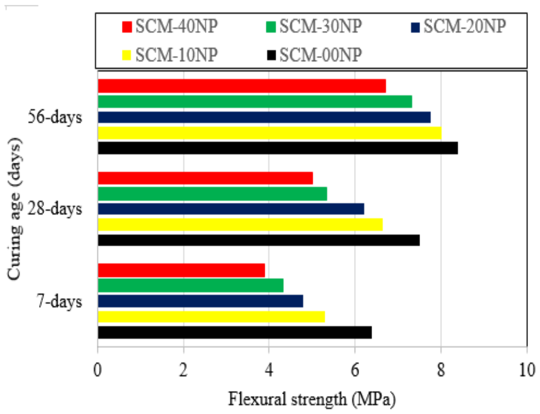

Fig. 8 Flexural strength results of SCMs, at different curing time

At 28-days curing, these reductions were changed to 11%, 17%, 28%, and 33%, respectively and to 5%, 8%, 13%, and 20% at 56-days, respectively for the same samples. This can be attributed to the pozzolanic reaction between cement and natural pozzolana that started after 7 days of curing.

3.4 Flexural bond strength

The substrate mortar (SUBM) was test at 28 days after casting and the results of the compressive flexural strength values were 30 and 5.3 MPa respectively, in normal water curing. However, these values are less (27 and 4 MPa) at hot climate. This is due to the water evaporation under such conditions, which limits the hydration process of the cement.

Figs. 9 and 10 shows the 28 and 56-days average value of the flexural bond strength and the

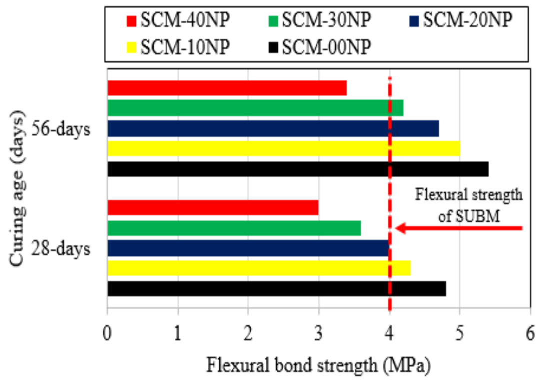

Fig. 9 Flexural bond strength of composites SCMs/SUBM, cured in hot climate

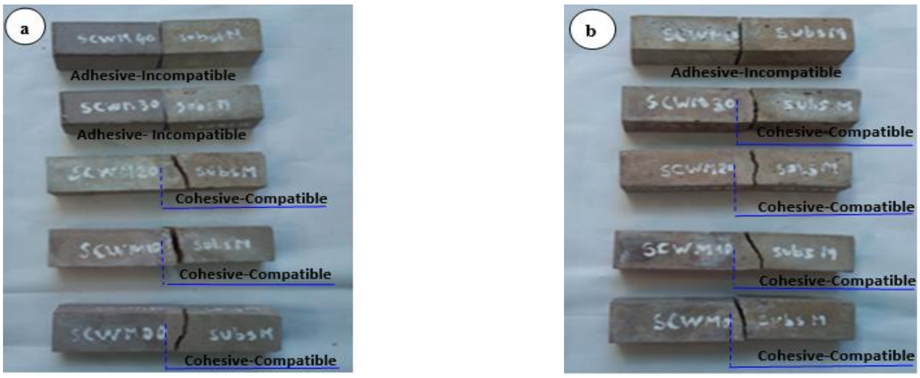

Fig. 10 Failure types of composite prism samples cured in hot climate: (a) at 28-days curing and (b) at 56-days curing

notable failure modes respectively, of all SCMs/SUBM composite prism specimens cured in hot climate. It can be observed that natural pozzolana improve flexural bond strength at hot climate a later age. The SCM-00NP/SUBM composite prism specimen showed the highest values followed by the (SCM-10NP/SUBM), then the (SCM-20NP/SUBM), then the (SCM-30NP/SUBM) and at the end (SCM-30NP/SUBM).

The flexural bond strength values at the 28-days curing were in ranges of 4.8 to 3 MPa for the repaired composite samples with 0% and 40% NP respectively. At the same curing period, the composite samples containing 10%NP (SCM-10NP/SUBM) and 20%NP (SCM-20NP/SUBM) showed flexural bond strength values greater than the flexural strength of the substrate mortar curing at hot climate (see Table 4). As a result, the failure mode of these composite samples, occurred entirely at the substrate, which means that the mortar is compatible with the substrate as shown in the Fig. 10. Beyond the replacement of the white cement with 20% NP the flexural bond strength values was smaller than the flexural strength of the substrate mortar. Failure modes observed for the SCM-30NP/SUBM and SCM-40/SUBM composite samples occurred along the interface, which resulted in a total separation between the repair mortar and the substrate.

At 56-days curing, flexural bond strength values were in ranges of 5.4 to 3.4 MPa for the SCM-00NP/SUBM and SCM-40NP/SUBM composite samples, respectively. The SCM-10NP/SUBM composite sample showed a flexural bond strength value close to that of the SCM-00NP/SUBM control composite. Furthermore, the adhesion between the repair mortar containing 30% natural pozzolana was improved compared to that recorded at the same curing period. Indeed, the SCM-30NP/SUBM composite sample showed a greater flexural bond strength value than the flexural strength of the substrate mortar, and no interface failure was observed as shown in Fig. 10. The development of flexural bond strength of composite samples containing 10%, 20% and 30% NP, at 56-days curing, is closely related to the addition of NP which reduces the large pores and eliminates the growth of calcium hydroxide ($Ca(OH)_2$), which is relevant to enhance interfacial properties between repair material and mortar substrate (Ollivier and Maso 1995, Leemann and Munch 2006). While, replacing white cement with 40% NP results in poor ITZ between SCM-40NP and parent mortar as noted by its failure mode.

4. Conclusions

From the results of this study, the following conclusions can be summarized:

• In order to obtain the desired target flowability of the produced repair mortars mixtures. It has been observed that the efficiency of acrylic copolymer on the SCM increases as NP content increases up to 40% (12.4 kg), whereas the efficiency decreases with NP content up to 10% (10.8 kg).

• The compressive and flexural strength of SCMs increases from 7-days to 56-days of curing with replacement levels of 10%, 20%, 30% and 40% of white cement by natural pozzolana. It was observed that in all self compacting repair mortars samples containing natural pozzolana, there was a noticeable gain in strength from 28-days onwards, while this was noted during the first 28-days in control mortar samples (100% white cement). For all curing times, it can also be seen that the compressive and flexural strength results indicated that the optimum white Portland cement replacement with natural pozzolana was at 10 wt.%.

• The three-point bending test confirms that the manufactured repair mortars containing 10%, 20% and 30% natural pozzolana showed good adhesion with mortar substrate at hot climate, as the cure time increases. This bonding ability improvement can be attributed to the pozzolanic reaction. The findings suggest that SCM is a promising material for the repair of hot climate damaged concrete structures. Beyond the replacement of cement with 30% natural pozzolana, failure consistently occurred along the interface.

References

Anisuddin, S. and Khaleeq, S. (2005), "Deterioration and rehabilitation of concrete structures in hot and arid regions", *Proceedings of the Association of Researchers in Construction Management 21st Annual Conference.*

Asteris, P., Tzamtzis, A., Vouthouni, P. and Sophianopoulos, D. (2005), "Earthquake resistant design and rehabilitation of masonry historical structures", *Pract. Period. Struct. Des. Constr.*, **10**(1), 49-55.

ASTM C78/C78 M, Standard test method for flexural strength of concrete (Using simple beam with third-point loading), ASTM International.

Benyahia, A., Ghrici, M., Choucha, S. and Omran, A. (2017b), "Characterization of fiber reinforced self-consolidating mortars for use in patching damaged concrete", *Latin Am. J. Solid. Struct.*, **14**(6), 1124-1142.

Benyahia, A., Ghrici, M., Mansour, M.S. and Omran, A. (2017a), "Elaboration and characterization of fiber-reinforced self-consolidating repair mortar containing natural perlite powder", *Adv. Concrete Constr.*, **5**(1), 1-15.

Corinaldesi, V., Monosi, S. and Ruello, M.L. (2012), "Influence of inorganic pigments' addition on the performance of coloured SCC", *Constr. Build. Mater.*, **30**, 289-293.

Courard, L. (1998), "Contribution à l'analyse des paramètres influençant la création de l'interface entre un béton et un système de réparation. Appétence et adhérence: cause et effet d'une liaison", Université de Liège, Belgique.

Courard, L., Darimont, A., Degeimbre, R., Willem, X., Geers, C. and Wiertz, J. (2002), "Repairing concrete with self compacting concrete: Testing methodology assessment", *Self-Consolidating Concrete*, 267-274.

Domone, P. and Jin, J. (1999), "Properties of mortar for self-compacting concrete", *Proceedings of the 1st International RILEM Symposium on Self-Compacting Concrete*.

EFNARC (2005), The European Guidelines for Self-Compacting Concrete: Specification, Production and Use, European Federation for Specialist Construction Chemicals and Concrete Systems.

EN 12190-6 (1999), Products and Systems for the Protection and Repair of Concrete Structures-Test Methods-Determination of Compressive Strength of Repair Mortar.

EN 1504-3 (2006), Products and Systems for the Protection and Repair of Concrete Structures, Definitions.

EN 197-1 (2000), Cement, Composition, Specifications and Conformity Criteria for Common Cements.

EN 934-2 (2009), Admixtures for Concrete, Mortar and Grout-Part 2: Concrete Admixtures-Definitions, Requirements, Conformity, Marking and Labeling.

EN196-1-(2006), Methods of testing cement - Part 1: Determination of mechanical strengths.

Ezziane, K., Bougara, A., Kadri, A., Khelafi, H. and Kadri, E. (2007), "Compressive strength of mortar containing natural pozzolan under various curing temperature", *Cement Concete Compos.*, **29**(8), 587-593.

Faria, P. and Henriques, F. (2002), "The effect of hydraulic components on lime mortars", *XXX IAHS World Congress on Housing-Housing Construction: An Interdisciplinary Task,*.

Felekoğlu, B., Türkel, S. and Altuntaş, Y. (2007), "Effects of steel fiber reinforcement on surface wear resistance of self-compacting repair mortars", *Cement Concete Compos.*, **29**(5), 391-396.

Feng, N., Li, G. and Zang, X. (1990), "High-strength and flowing concrete with a zeolitic mineral admixture", *Cement Concrete Aggregat.*, **12**(2), 61-69.

Ferrara, L., Park, Y.D. and Shah, S.P. (2007), "A method for mix-design of fiber-reinforced self-compacting concrete", *Cement Concrete Resear.*, **37**(6), 957-971.

Ghrici, M., Kenai, S. and Meziane, E. (2006), "Mechanical properties and durability of cement mortar with Algerian natural pozzolana", *J. Mater. Sci.*, **41**(21), 6965-6972.

Ghrici, M., Kenai, S. and Said-Mansour, M. (2007), "Mechanical properties and durability of mortar and concrete containing natural pozzolana and limestone blended cements", *Cement Concete Compos.*, **29**(7), 542-549.

Güneyisi, E. and Gesoğlu, M. (2008), "Properties of self-compacting mortars with binary and ternary cementitious blends of fly ash and metakaolin", *Mater. Struct.*, **41**(9), 1519-1531.

Haque, M. and Kayali, O. (1998), "Properties of high-strength concrete using a fine fly ash", *Cement Concrete Resear.*, **28**(10), 1445-1452.

Kaid, N., Cyr, M. and Khelafi, H. (2015), "Characterization of an Algerian natural pozzolan for its use in eco-efficient cement", *Int. J. Civil Eng.*, **13**(4A), 444-454.

Kuder, K.G., Ozyurt, N., Mu, E.B. and Shah, S.P. (2007), "Rheology of fiber-reinforced cementitious materials", *Cement Concrete Resear.*, **37**(2), 191-199.

Leemann, A., Münch Gasser, B.P. and Holzer, L. (2006), "Influence of compaction on the interfacial transition zone and the permeability of concrete", *Cement Concrete Resear.*, **36**(8), 1425-1433.

Liu, B., Xie, Y. and. Li, J. (2005), "Influence of steam curing on the compressive strength of concrete containing supplementary cementing materials", *Cement Concrete Resear.*, **35**(5), 994-998.

López, A., Tobes, J., Giaccio, G. and Zerbino, R. (2009), "Advantages of mortar-based design for coloured self-compacting concrete", *Cement Concete Compos.*, **31**(10), 754-761.

Moropoulou, A., Bakolas, A. and Anagnostopoulou, S. (2005), "Composite materials in ancient structures,"

Cement Concete Compos., **27**(2), 295-300.
Neville, A. (2000), “Good reinforced concrete in the Arabian Gulf”, *Mater. Struct*, **33**(10), 655-664.
Ohama, Y. (1998), “Polymer-based admixtures”, *Cement Concete Compos.*, **20**(2-3), 189-212.
Ollivier, J., Maso, J. and Bourdette, B. (1995), “Interfacial transition zone in concrete”, *Adv. Cement Mater.*, **2**(1), 30-38.
Pavlidou, E. (2011), “Systematic analysis of natural pozzolans from Greece suitable for repair mortars”, *J. Theor. Anal. Calorim.*, **108**(2), 671-675.
Ramli, M. and Tabassi, A.A. (2011), “Influences of polymer modification and exposure conditions on chloride permeability of cement mortars and composites”, *J. Mater. Civil Eng.*, **24**(2), 216-222.
Rodrıguez-Camacho, R. and Uribe-Afif, R. (2002), “Importance of using the natural pozzolans on concrete durability”, *Cement Concete Resear.*, **32**(12), 1851-1858.
Şahmaran, M., Christianto, H.A. and Yaman, İ.Ö. (2006), “The effect of chemical admixtures and mineral additives on the properties of self-compacting mortars”, *Cement Concete Compo.*, **28**(5), 432-440.
Silva, P.R. and Brito, J.D. (2015), “Fresh-state properties of self-compacting mortar and concrete with combined use of limestone filler and fly ash”, *Mater. Resear.*, **18**(5), 1097-1108.
Sridevi, K.A., Sudhahar, D.L., Babu, V. and Venkatasu Bramani, R. (2017), “Experimental study on the development of self compacting mortar for casting ferrocement elements”, *I Int. J. Adv. Eng. Resear. Stud.*
Veiga, M.R., Velosa, A. and Magalhães, A. (2009), “Experimental applications of mortars with pozzolanic additions: characterization and performance evaluation”, *Constr. Build. Mater.*, **23**(1), 318-327.
Venkatesh, G., Vivek, P.S. and Dhinakaran, G. (2017), “Study on compressive strength of self compacting mortar cubes under normal & electric oven curing methods”, *IOP Conference Series: Earth and Environmental Science, IOP Publishing.*

JK