Global NEST Journal, Vol 25, No 9, pp 11-19

Temperature impact on the hydration and setting mechanism of C-S-H bonding on nano-biomass silica with poly-carboxylate ether

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Received: 07/07/2023, Accepted: 10/08/2023, Available online: 06/09/2023
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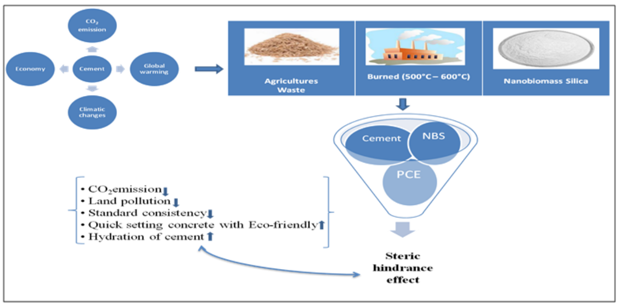
https://doi.org/10.30955/gnj.005227

Graphical abstract



Abstract

Pozzolanic material and a chemical admixture have been used in the current investigation; Nano Biomass Silica (NBS) and Poly-Carboxylate Ether (PCE). NBS produces 20% of the 590 million tonnes of paddy produced globally. Amorphous silica, a mineral component used in concrete, is present in sizable levels in these by-products (NBS). A binary and ternary of NBS with partial replacement of Ordinary Portland Cement (OPC) and the addition of PCE with varying dosage by weight of cement were used. This study's goal is to determine how they affect paste Setting time (ST) and Standard consistency (SC), and hydration temperature evaluation conducted in hot weather with various percentage at NBS from 6, 12 and 18% and PCE with varying dosage from 0.8, 0.9 and 1%. The chemical bond & structure of pozzolanic and chemical admixture in the FTIR were analysed. While PCE showed very little impact on consistency, higher w/b ratios with higher NBS levels were required for the maintenance of OPC-NBS paste consistency standards. The Initial setting time (IST) & Final setting time (FST) for binary OPC-NBS pastes significantly raise to 6% NBS, followed by a decrease at 12% and 18% NBS. However, for OPC-PCE pastes, the IST increased to 0.8%PCE followed by decrease at 0.9% and 1% PCE. In cement paste, PCE can be added as an additive, but the FST increases with an increase in the PCE percentage. At the same time, the mineral admixtures NBS can be used as a cement paste to decrease the FST and also reduce agricultural waste. NBS will effectively use silica ash as a microstructure filler as an additive in manufacturing to produce a certain form of cement with specific IST and FST, in particular for the sustainability of building materials and in hot weather.

Keywords: NBS, PCE & pozzolans, consistency standards, setting times

1. Introduction

As soon as cement particles come into contact with water, the cement becomes hydrated. It takes a while for the so-called "setting process" to convert cement paste from a liquid state to a porous, solidified state. It can still be easily divided into five stages that are usual, based on the outcomes of early heat release experiments where the heat flow is proportional to the rate of response. On the durability and later macroscopic mechanical properties of cement-based materials, the microstructure and early hydration reaction process play a significant role. In addition to being a crucial part of cement-based products, cement paste is also a sophisticated multi-phase heterogeneous composite. The chemical and physical modifications in cement paste affect the setting time and hardening of cement-based materials. Investigation of the rule of setting time, penetration and hydration of chemical and mineral admixture combined cement paste in various temperature levels, it aids in better comprehension of the early performance of chemical and mineral admixture combined cement based materials.

The moment the water and cement are combined, the hydration product creation begins. Concrete initial and final setting times can be predicted using the stiffness of the matrix. According to the beginning of the cement mixture's hardening phase is referred to as the initial setting time of concrete. As the predominant trend for industrial development, an environment-friendly given development system with a saved resource is now drawing more and more attention (Naik T.R et al., 2001). About 5 to 8% of the CO_2 emissions caused by humans come from the manufacturing of Portland cement (World Energy Council, 1995). Clinker replacement with supplemental cementitious materials is one of the best ways to significantly lessen its environmental impact (SCM). Finding novel sources of SCMs, combining different types of SCMs, and analyzing how these affect cement and concrete qualities has all been the subject of extensive research. Additional cementations' materials (SCM) include coal FA, BFS, SF, and NBS (Juenger et al., 2019). Which improve and regulate physical characteristics, such as strength and durability, and which lower related CO_2 emissions. Understanding how an organic super plasticizer interacts with inorganic cement SCM particles is crucial for producing high performance concrete with acceptable workability and flow characteristics (Ben Aicha, and Mouhcine 2020).

Small-scale biomass pozzolanic substance, silica is a by-product of agricultural waste produced by burning rice husk is a rotary furnace at 500-600°C. It possesses a high silica concentration of 90% to 95% (Hossain. SK et al., 2018). More C-S-H gel is created when amorphous silica interacts with hydration products. An excellent cementing silicate is changed by the pozzolanic process.

Calcium hydroxide/Portlandite ($Ca(OH)_2$) + Silica acid (H_4SiO_4 or $Si(OH)_4$)

$Ca(OH)_2 + H_4SiO_4 \rightarrow CaH_2SiO_4.2H_2O$
(Calcium Silicate Hydrate)
CH + SH → C-S-H

As a result, mechanical and durable qualities of cement are improved (Bruno Ribeiro et al 2020). Chemical nature of the ash, the amount of silica in it, and the mineralogical structure of NBS are all largely dependent on the combustion time, temperature, and turbulence. NBS is five times less expensive than silica fume. Benefits of NBS incorporation in concrete are,

1. Reduction in the heat of hydration and stoppage of cracks from forming during casting.
2. Reduction in permeability and making chlorids and sulphate penetration difficult (Nehdi. M et al 2003).

As a result, a majority of researchers plan to make concrete using RHA as a substitute for cement. Their studies show the ability of rice husk to improve the durability & compressive strength of concrete (Zhang. M.H and Malhotra M.V, 1996; Qingge Feng et al., 2004). NBS with a pozzolance index of 69% was made from rice husk (Adnan Suraya Hri et al., 2012). Concrete made Nano Biomass Silica can help environment. Concrete's ability to withstand water penetration reduces as cure time increases. There is also evidence of a linear relationship between water permeability and water penetration depth (Prameetthaa. J et al., 2015). A few researchers have used NBS with partial cement replacement in their investigation of the workability and water absorption of concrete. NBS has a large capacity for water absorption. This is brought about by its cellular characteristics, which result in the high absorption capacity of cement and low water availability for workability. The workability of concrete declines with increases in NBS concentration (Zhang. L et al., 2019). A group of substances known as chemical admixtures are capable of making considerable changes in the macroscopic characteristics of cement and concrete when introduced in modest quantities (Roncero. J et al 2002). Chemical for tailoring the properties of concrete mixes for specific purposes and, increasingly, for concrete with low carbon footprints (Prameetthaa. J et al., 2015; Kismi et al., 2012)

Low cementitious concrete is becoming increasingly popular as demand for urban buildings and traffic facilities rises. In order to satisfy the use of concrete in varied environmental circumstances and increase its performance, low cementitious concrete must be used in sufficient amounts (R.J. Flatt et al., 2012). Concrete's performance can be impacted by bleeding rate in several ways. Concrete's performance can be changed by adding additives in order to regulate bleeding rate. Superplastizers are among these chemical admixtures that are mostly used to improve concrete's capacity to flow at low water-to-cement ratios (W/C) and effectively control bleeding (Zhang. Y.R et al., 2017). Cement particles can be dispersed via an electrostatic repulsion mechanism by the first generation of super plasticizers, Sulphonated naphthalene formaldehyde condensates (SNF) and amino sulphonate-formaldehyde condensates are two examples (ASF). The new SP generation is based on poly-corboxylate ether polymers that have side chains made of poly (ethylene oxide) (PEO) and carboxylic groups. In comparison to the previous generation, PCE copolymers function better because they can provide both electrostatic repulsion and steric hindrance (Kreppelt. F et al., 2002; Robler. C et al 2008; Siler. P et al., 2014). PCEs are better than other varieties of SPs since it is simple to alter their molecular weight and side chain lengths. The steric barrier prevents the grains from clumping together. The associated water that has been released improves usability and allows for water savings of up to 40% (Hu. J et al 2014). By creating hydrogen connections between the silanol groups on the silica surface and the terminal hydroxyl groups on polyethylene glycol graft chains, poly-carboxylate-based super plasticizers interact with cement and silica fume particles through surface adsorption. Through electrostatic repulsion and steric barrier, this promotes particle dispersion. The use of silica fume, fly ash, and blast furnace slag in place of Portland cement has lately led to the development of new, high-strength alkaline-earth-activated concretes with a very low w/c ratio of 0.16 and a very low embodied CO_2 level (Khan. Sadaqat Ullah et al., 2014). Our hypothesis is that the super plasticizer initially binds to the extremely large surface area of the Nano Biomass Silica particles, and that as the temperature increases; this causes fast changes in the cement paste's setting time. Could open up a new route for making long-lasting, low-CO_2 concretes that are workable at very low water contents.

1.1. Mechanism of poly-carboxylate ethers (PCE)

As demonstrated in Figure 1, the activity of the polycarboxylate ethers (PCE)-based super plasticizers causes the cement particles to spatially split (through steric hindrance). Side chains are arranged in a precise pattern along a main chain in PCEs plasticizers. There is a possibility that the cement grain's capacity to cause polymer adsorption and steric repulsion functions as a mechanism for cement grains' dispersion (Y.H. Kwon et al 2017; Y. Alrefaei et al 2019).

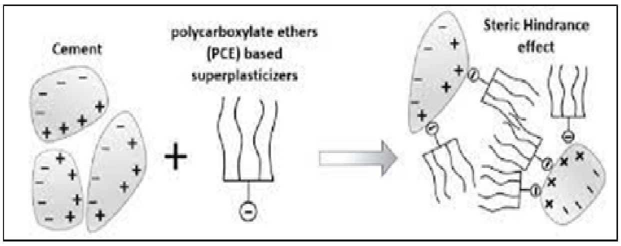


Figure 1. Mechanism of the super plasticizer poly-carboxylate ethers (PCE) modified (Y. Alrefaei et al 2019)

2. Materials

2.1. Cement

Ordinary Portland Cement (OPC) from the cement manufacturer was used in this investigation. The chemical and mineral components of the used cement are listed in Table 1.

2.2. Nano biomass silica (NBS)

NBS was produced by burning the rice husk at 500°C - 600°C. It processes a high silica concentration of 90% to 95%. The particle size is reduced by using a jar mill for about an hour. NBS produced from controlled burning has a high concentration of amorphous silica, which is included as a mineral additive to concrete. Table 1 provides a breakdown of the cement's chemical and mineral components.

2.3. PCE

Super plasticizer made from poly-carboxylate ether was created in accordance with Ref 24 (F. Winnefeld et al., 2007). Figure 2 shows a schematic representation of its chemical composition. The two monomers that make up the co-polymer each serve a different purpose. When the carboxylic group COONa dissociates into COO- and Na+, the carboxylic group in the co-polymer gives the $-^{ve}$ charge on the main chain. Polyethylene oxide (PEO), a monomer grafted on the main chain whose length is dependent on the number of P units, supplies the side chain length. The side chains employed in this investigation had a length of 23 PEO units, a grafting density of 6:1, and a grafting density of n:m. This mixture's comparatively high charge density allows for effective adsorption on ettringite and ordinary Portland cement (OPC) (A. Zingg et al 2008). Results from size exclusion chromatography show that the mass-average molecular weight (Mw) is 18,900 g/mol, the number-average molecular weight (Mn) is 7600 g/mol, and the polydispersity index (Mw/Mn) is 2.5 (SEC).

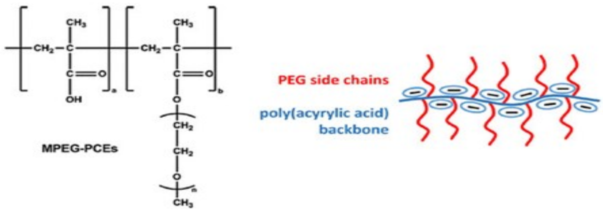


Figure2. Chemical composition of PCE; n= anionic carboxylic group, p= PEO unit, m= Side chain.25

Table 1. OPC and NBS compositions and physical and chemical characteristics

Oxside	Compositions (%)	
	OPC – 53	**NBS**
SO_2	28.2	94.25
Al_2O_3	4.9	0.343
Fe_2O_3	2.5	0.581
CaO	50.4	1.18
MgO	3.1	0.872
SO_3	2.3	-
Na_2O	0.2	0.590
K_2O	0.4	-
TiO_2	-	2.078
Cl	-	-
Free lime	-	-
Bogue's composition (%)	OPC	NBS
C_3A	8	7
C_3S	56	59
C_2S	16	10
C_4AF	9	9
Properties	OPC	NBS
Loss on ignition	-	-
Specific surface area (m^2/s)	225 (m^2/kg)	562 (m^2/kg)
Ini setting time (mins)	91min	45min
Fin setting time (mins)	211min	-
Standard consistency (%)	31.5%	32-33.5%
True material density (g/cm^3)	1440kg/m^3	-
Specific gravity	3.15	
Normal consistency	31%	33%

2.4. *Fineness test of cement and nano biomass silica*

The test sample material (Cement & NBS) 800grms IS: 90micron sieve and sieve shaker were utilised. For determination of the percentage weight of the residue over the total sample reported for 15 minutes. It was taken to see the remainder did not exceed 10%.

Figure 3. Retained M-S

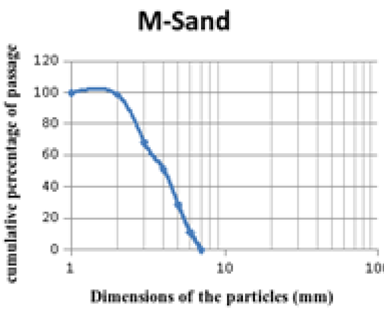


Figure 4. Sand particle size analysis graph

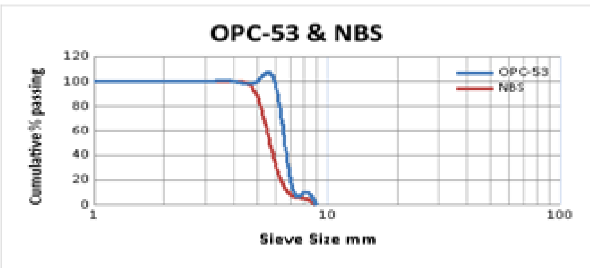


Figure 5. Particle size analysis graph on OPC – 53 & NBS

In this study, rice husk-derived Nano Biomass Silica with an average particle size of 18 micrometers (produced by Aastraa Chemicals, Chennai, India) was used. Sand in accordance with IS 650:1991 (Ref. 28; Indian Standards). The mortar studies used specifications. The table reports the oxides found in NBS and regular Portland cement (OPC): 1. It should be noted that NBS contained 95.17%, or more than 70%, of the principal oxides (SiO2, Al2O3, and Fe2O3), making it an excellent pozzolanic material. An increase in the fineness of cement particles caused an increase in workability (Suraya Hani Adnan et al., 2009). Figures 4 and 5 indicate the particle size analysis for each of them. The setting times (initial and final setting time) for sizes 150µm - 75µm to an initial setting time of 140min – 30min for sizes 45µm - 0µm There was a reduction in the final setting time from 300min to 240min with an increase in cement fineness. Detects of M-Sand, NBS, and cement of all particles size are given below 10µm.

2.5. *Mix design*

First, freshly made cement pastes using the chosen PCE doses, NBS, and w/c ratios for the cement were made. The PCE dose (by mass of cement) was adjusted in 1.0% increments between 0.0% and 0.8%, 0.9% by weight of cement, and NBS to replace the cement material in various percentages at the following levels: 0%, 6%, 12%, and 18%. Water containing different PCE concentrations, which were present in the PCEs, were added during mixing.

3. Methods

3.1. *Cement paste preparation*

OPC-53, a common type of Portland cement, was utilized in this research. The cement pastes' washroom temperature was set at in cement paste, various co-polymer and NBS concentrations were applied (exact amounts are mentioned in the coming sections). The co-polymers were manually combined with cement for 180 seconds after being first dissolved in demonized water. The resistivity of the deionizer water used in this investigation is about 18–18 MΏ.

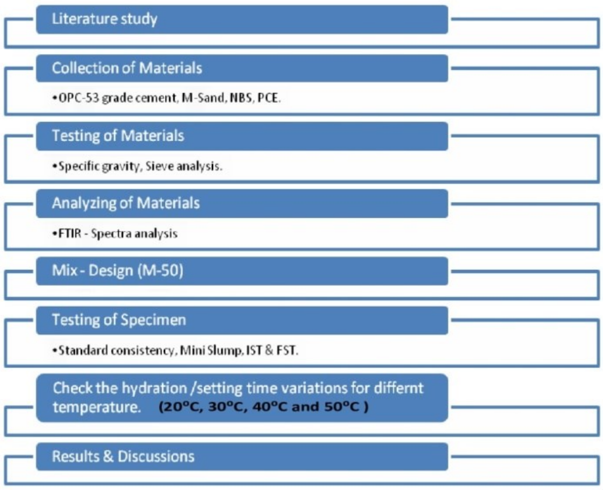


Figure 6. Methodology

3.2. *Overview of methodology*

Figure 6 Methodology, the stages are those seen in relevant literature with a careful reading of their implications. Materials used in the moisture were gathered after completion. Cement, FA, CA, mineral waste, PCE, & water were included in the material collection. To investigate their effect on Cement, NBS and PCE were defined using Fourier Transform Infrared Spectroscopy (FTIR). In the investigation of their effect on cement as also their effect of NBS on setting time variations for various temperatures like 20̊ C – 50̊ C.

3.3. *Water reduction capacity and the mini slump test*

By evaluating paste flow, time-dependent slump loss, and the highest feasible water reduction, the performance of the synthesized co-polymers in Ordinary Portland Cement and Nano Biomass Silica was evaluated. The ratio of cement paste's water to cement (w/c) without a copolymer and with co-polymer spread values were calculated as part of this test. The necessary volume of water was added to a mixer, where the copolymer was dissolved. When using the aqueous copolymer solutions, the amount of mixing water was reduced by the amount of water in the solutions. In this test, cement paste is poured into a truncated cone-shaped mould that has a height of 57mm, a bottom dia of 38mm, and a top dia of 19mm. After lifting the mould, the spread dia is measured. The amount of time needed for the paste to thicken to a 15mm diameter was also calculated. Additionally, visual inspection aids in assessing the bleeding and segregation of the paste.

3.4. Standard consistency measurement

The quantity of water required to for making a plastic mix is referred to as standard consistency. The fineness of the binder determines the typical consistency of the cement paste.

4. Results and discussion

4.1. Characterization of PCE, OPC, and NBS

Figure 7 displays the PCE's FTIR Spectra. Vibrations that reach out C=O is believed to be the cause of peaks at 1715 cm-1. Vibrations that reach out C-O is shown by the peaks at 1272 and 1105 cm^{-1}. The peak of the O-H deformation vibration is at 1403 cm^{-1}, while the peak of the C-O-C stretching vibration is at 1042 cm^{-1}. Given that there is no absorption peak of C=C at 1620-1680cm^{-1}, it indicates that each monomer has been successfully polymerized and PCE was obtained.

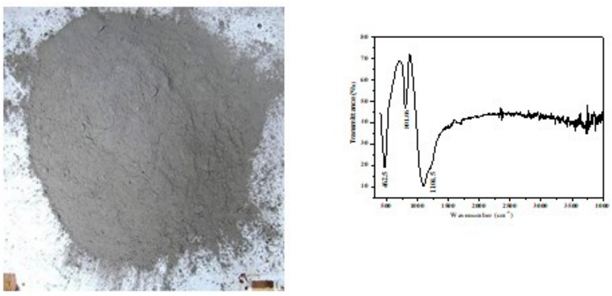


Figure 7. OPC – 53 & FTIR spectrum of OPC

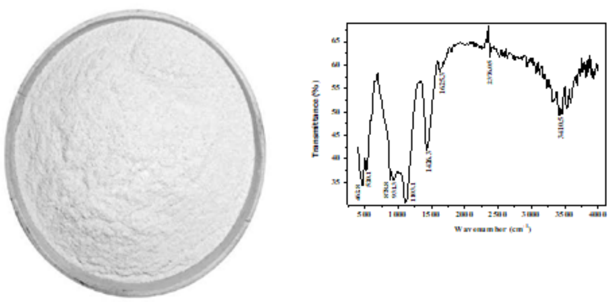


Figure 8. NBS & FTIR spectrum of NBS

In Figure 8's FTIR spectrum of the OPC, there are peaks at 801cm-1 in the stretching vibration of Si-O-Si. Peaks at 1104 cm-1 are thought to be caused by Si-stretching O's vibration. Figure 9 displays the NBS's FTIR Spectra. Peaks at 1103 cm-1 are associated with C-stretching O's vibration. The stretching vibration of O-H is represented by peaks at 3410cm-1 in both samples, but the bending vibration of O-H in water chemically bonded to KBr crystal is represented by peaks at 1625cm-1.[28] PCE showed peaks by NBS, indicating that NBS/PCE has been successfully synthesized.

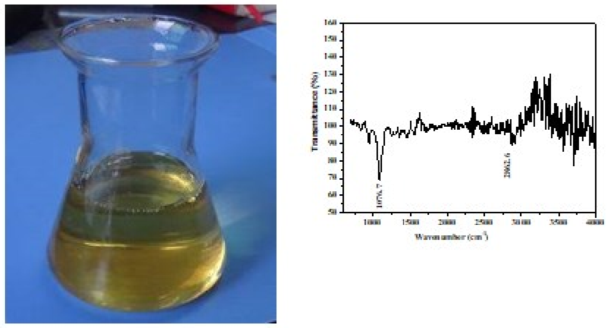


Figure 9. PCE & FTIR spectrum of PCE

4.2. Effect of Standard Consistence of OPC-NBS/ OPC-PCE

Figure 10 presents the findings for the various binary pastes, showing the w/b proportions at standard consistence. With an increase in NBS replacement levels, For NBS binary pastes to have uniformity that meets standards, the w/b ratio needed raised. In contrast, the w/b ratio required for standard consistency with PCE binary paste was the same at all levels as it was for OPC.

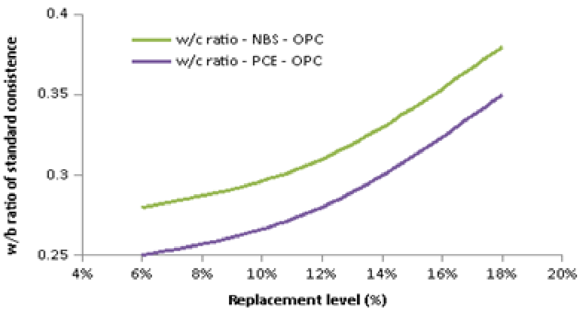


Figure 10. Binary NBS-OPC and PCE-OPC Pastes at Standard Consistency

There was discussion of the properties of Portland cement in standard consistency under water binder (w/b) ratios. The numerical values of the w/b ratios were found to be strongly associated with the distances between the cementations' particles in a cement paste as the hydration process got under way. The results, which have a consistent consistency and reveal the water/binder ratios for the several binary pastes, are displayed in (Figure 10). Modest variations in the typical fluidity of cement with various NBS contents. The standard consistency increased as different percentages of NBS were used in place of cement. The requirement for more water to maintain the correct consistency and the finer NBS particles were the causes of this. In contrast, the w/b ratio required for PCE binary paste was comparable to that for OPC at all levels for the provision of standard consistency. Due to excellent, which included their high dispensability, capacity to reduce water content, and ease of molecular structure alteration. A larger quantity of water was needed for wetting its surface than for PCE or OPC, due to the significantly larger surface see in NBS.

4.3. *Effects of mineral admixtures generally*

Figures 11 to 14 depict the times required for concrete mixtures with mineral admixtures to build up. It is obvious that the overall effect of the various mineral admixtures is to extend the time that concrete takes to set. The observed delay in setting times can be primarily attributable to the combined effects of a reduced cement content and a greater "effective super-plasticizer (PCE) dosage" relative to the weight of cement since some of the cement in these concrete mixes was replaced by the mineral admixtures. The typical impact of super-plasticizers, according to previous reports, is to delay the setting periods of concrete, with the degree of delay depending on the kind and dose of super-plasticizer, the type of cement, and the temperature.[29] Tricalcium silicate (C_3S), which gives concrete its initial strength and tricalcium aluminate are two cement compounds whose hydration is often postponed by a super plasticizer (C_3A). The adsorption of super plasticizer to the cement particle surfaces is what causes the slowing of hydration. Considering concrete mixes using mineral admixtures have lower cement content and higher effective super plasticizer dosage; a stronger retarding impact may be anticipated. The super plasticizer and MA influence on the cement particles' dispersion may also have slowed the setting times. This is due to the theory that two key processes coagulation, which creates connections between particles, and the production of hydrates, which iridize the coagulation structure are required for cement paste to set (Alessi. A et al 2013). The cement particles should be packed closer together in OPC concrete because compared to the other mixes; it contains a higher percentage of cement and a lower effective super plasticizer dosage. Greater interparticle interaction could occur from this, which could hasten setting. Depending on the onset and rate of the pozzolanic reaction, the shift in setting times may also be attributable to the mineral admixtures.

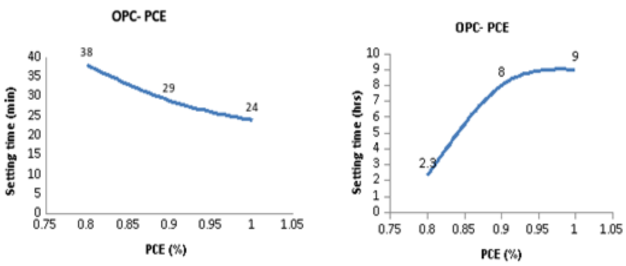


Figure 11. Initial & Final setting of OPC – PCE

4.4. *Effects of the admixture for water reduction*

The impact of the WRA on the initial & final setting times is shown in Figures 11 and 12 from these results depict the variations in the beginning and the final setting time at OPC-PCE paste composition standards. Although the rise of 1% PCE was much bigger than for the other intervals, the initial setting times for the OPC-PCE blends decreased and the final setting times increased with increasing PCE admixture concentration. Even when the high water was decreased, the increase in setting time for the HSC mixes where the PCE was more pronounced and consistent. The impact of the water/cement ratio & the setting times may have been mitigated by the effect of the super plasticizer.

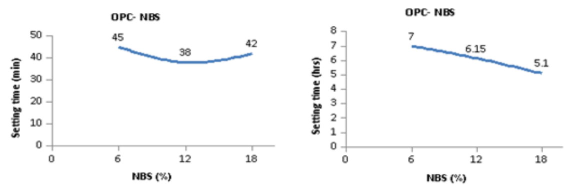


Figure 12. Initial & Final setting of OPC – NBS

4.5. *Effect of the mineral admixtures' replacement level*

The typical effect of increasing the replacement amount of mineral admixtures is effect of making concrete set up more slowly. These will be influenced by a combination of the earlier indicated higher effective super plasticizer dosage and a lower Ordinary Portland Cement component. When the variation in the setting periods of the final and initial OPC-NBS and OPC-NBS-PCE pastes in considered as shown in Figures 13 & 14 For NBS paste, the initial setup time of OPC-NBS exhibited a significant rise at 6% NBS, a minor drop at 12% NBS, and then an additional increase at 18% NBS. Finally, there was a hardening of the blending time of OPC – NBS blend. This early setting time indicator a non-systematic contribution and influence of the NBS on hydration and setting. There was a lowering of the initial setting time where, there was growth of NBS content. There was no substantial to the changes in IST during replacement of NBS in smaller quantities.

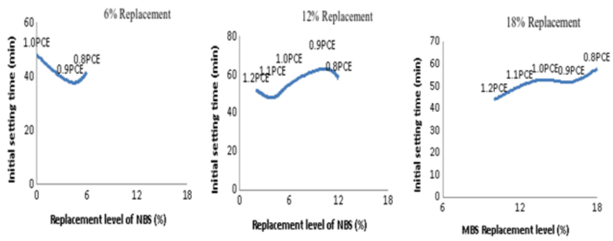


Figure 13. Initial setting time of OPC – PCE – NBS

For ternary binders with a fixed PCE content, the general trend of prolonged IST & FST with rising NBS content was still evident. But, results increase in PCE content variations were seen in the setting time of NBS content that was non - systematic, closely following the variations in the setting time of the binary OPC – NBS merges with increase in PCE content (Figures 11 & 12). That is, there was a noticeable increase in setup time when PCE was increased from 0.8% to 0.9% to 1.0%, and an even greater rise in setup time when PCE was increased from 1.1% to 1.2%. However, the setting time minimum did shifted to lower PCE content at total replacement levels (i.e., 12%). Similar initial and ultimate setting durations of mortar with NBS blend as binder and up to 10% NBS have been reported (Suraya Hani Adnan et al., 2009; Kantro DL, 1980).

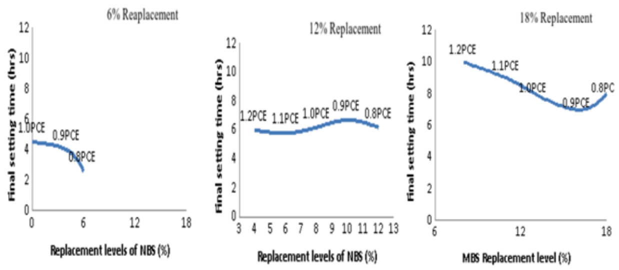


Figure 14. Final setting time of OPC – PCE – NBS

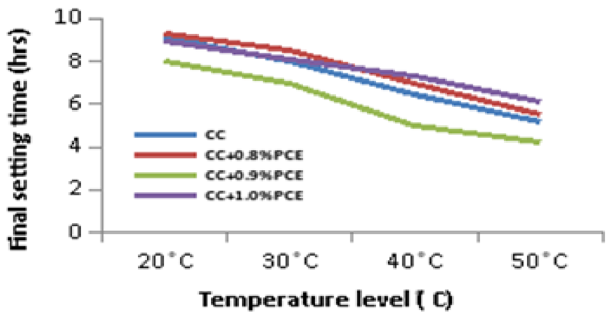


Figure 15. Final setting time of various temperature (0% NBS)

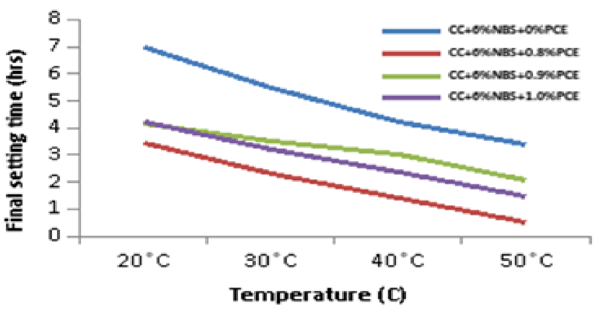


Figure 16. Final setting time of various temperature (6% NBS)

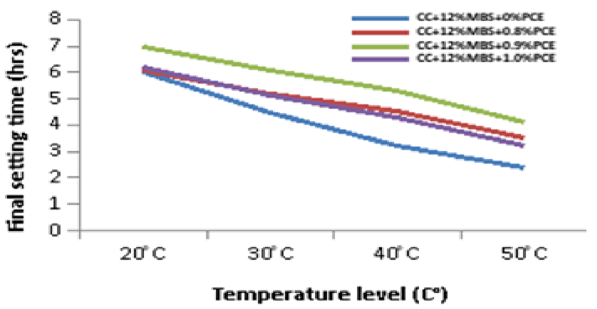


Figure 17. Final setting time of various temperature (12% NBS)

4.6. Effect of temperature on setting time

Curves shown Figures 15 through 18 shared a general profile, though at various rates. The early hydration response, showed up promptly (between 0 and 30 minutes) for OPC and with only a small difference from NBS and PCE mixtures, The primary reactions that occurred during the hardening phase were denoted by the corresponding maximum temperature.

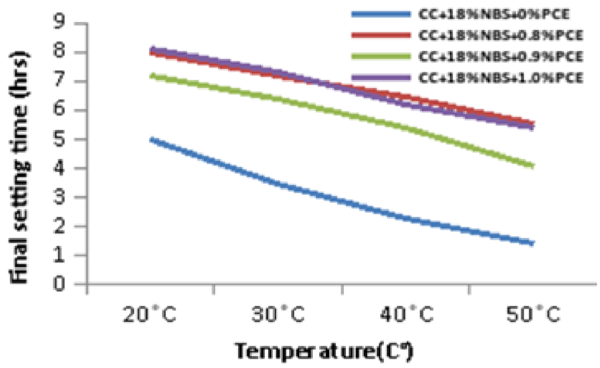


Figure 18. Final setting time of various temperature (18% NBS)

Figure 15 show the change in final setting time based on various temperature. A decrease in the final setting time was required increase in temperature and the PCE admixture level Figures 16 and 17 shows 6% and 12% of NBS replacement. The final setting time was very much less in comparison with OPC. To increase the % of PCE if final setting time was reduced because if polycorboxylate Ether admixture to produce heat for mixing process. So that increase the heat the hydration process runs quickly. The results of the binary OPC-PCE, OPC-NBS, and ternary OPC-NBS-PCE paste blends for standard consistence, IST & FST showed how each component of the blends affected the quality of water absorbed, both physically and through hydration and its affect on the hydration process. Use of the vicat equipment, showed that 31% of cement paste passed the standard consistency test. When different amounts of NBS were used for replacement of some or all of the cement, consistency of the blended cement paste was seen getting thicker. This was due to finer NBS particles, which required more water to maintain the desired consistency.

The significantly large specific surfaces of the NBS (29m^3/g) compared to the PCE, which was equivalent to the OPC (3.29m^3/g), accounted for its high-water consumption. The characteristics of the pastes, which were evaluated right away just after addition of water, were seen as related to the quality of water available for a decrease in viscosity and act as a lubricant.

5. Conclusions

The effect of addiction of additives like Polycarboxylate ethyl (PCE) and mineral admixtures like Nano Biomass Silica (NBS) to cement paste specimens was tested. The tests included sieve examination of the cement & NBS as well as their specific gravities. We examined the new cement paste's w/c ratio, consistency, IST & FST, and hydration temperature. The primary conclusions of the present investigation are that the presence of NBS increased the requirement for water in cement paste and raised the w/c ratio. The w/c ratio in the control sample was 0.27, while it was 0.29, 0.32, and 0.38 at 6, 12, and 18% NBS ratios, respectively. Extra water provided the cement gel ample time to hydrate.

The outcomes unmistakably showed the effects of mineral and chemical admixtures on binary paste standard consistency and setting times, that the latter showing the effects of variations on hydration:

1. Minimal impact of NBS on consistency makes partial OPC replacement unnecessary. Indirectly the need for a use in w/p ratios along with rising NBS. This is explained by the extremely high specific surface area of NBS and the high quantities of water adsorption/absorption that result. NBS functions as a largely inert substance throughout this time, despite a decrease in setting times, with increasing NBS until the point where rising NBS quantities produced decreasing separation distances between hydrated cement particles.
2. NBS concrete achieves lower water permeability than control concrete. Concrete's water permeability will decrease as NBS content is raised. Concrete that is exposed to a moist environment and is permeable to water can have its water permeability reduced with NBS.
3. As hydration products and amorphous silica interact, additional CSH gel is produced. Concrete gains strength and durability as a result. It is well known that incorporating agro-industrial wastes into concrete promotes ecologically friendly and sustainable growth, which in turn reduces carbon footprints and the amount of waste that needs to be disposed of in landfills.
4. A decrease w/b ratio is needed when PCE levels rise in order for maintenance of the acceptable standard consistency for PCE-OPC pastes. Binary OPC-PCE paste setting times do fluctuate in accordance with a rise in PCE content. Even at higher PCE levels, initial setting time increases but final setting time decreases due to increase in PCE causing production of heat during hydration, which reduces final setting time. Small doses of PCE cause further reduction in setting time.
5. Despite the fact that the mineral and chemical admixtures do not operate completely independently from one another, their impacts on consistency and setting times in binary are often reflected in the behaviour of ternary.
6. Concrete sets faster initially as the temperature of the field rises. There haven't been many research on the use of NBS as a cement substitute or additive in normal concrete, despite its enormous potential.

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