

Experimental study of admixture on Bentonite clay reinforced concrete as a partial substitute to cement

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Abstract. The mortar mixtures were prepared in various proportioned with cement to sand ratio of 1:3 and 1:4. The reinforced concretes were cast for the same flow level but different percentages of clay (0, 5, 10 & 15%) dosage. The prepared motor concrete subjected for structural study and mechanical property analysis. In FTIR spectra shows predominant peaks are observed the presence of admixture and clay in the concrete motor. The XRD spectra indicates the formation tetrahedrally arrangement of silicate and octahedrally arrangement of aluminate groups in clay mixed concrete. The surface morphology significantly improved upon adding of different admixture as examined in SEM image. The mechanical study revealed that the compressive strength increases with increase in clay percentages up to C-2 (10 wt %) due to the strong adhesion because of mixture of water reduce and water repellent which makes better compact and reduce porosity. The addition of slump flow improved due to presence of polycarboxylate ether and the evident workability loss started after the resting time of 25 min.

Key words: Admixture, Clay, Motor, Concrete

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1. Introduction

With the quick expansion in metropolitan development, land recovery has made the need to extend waterfront metropolitan regions. Be that as it may, the designing properties of dug waste in the waterfront regions are poor, and tremendous ground enhancements are needed prior to having the option to help framework [1 – 3]. Hydraulic driven concrete usage in concrete developed quickly as of late. Creation of concrete causes around 7% of whole globe CO₂ emanations, especially in clinker creation [4]. The bringing down of cement use in concrete was expected to limit CO₂ discharges into climate. Pozzolanic materials use will lessen the water driven concrete utilization in concrete [5, 6]. Usage of Industrial wastes like fly ash, GGBS, Silica fume etc. as substitute material to cement will reduce the cement usage in concrete. Now-a-days fly ash utilization in concrete became very common practice. Coal based thermal power plants generates most of the fly ash. Cementitious specialist is a well known technique used to

upgrade delicate earth establishments [7]. It frames a stable translucent compound through its own hydration and an auxiliary pozzolanic response with earth minerals, viably upgrading the strength of delicate clay. The strength of the cement-based stabilized soft clay is improved by adding a specific measure of coarse particles to shape sand-clay-cement- water paste [8].

The small size of the particles and their remarkable gem structures give clay materials unique properties. These properties such as cationic exchange capacities, plastic behavior in wet condition, catalytic capacities, water absorption capacity, and low permeability made the clay unique and suitable for cement concrete [9 -11]. The characterizing mechanical property of clay is its pliancy when wet and its capacity to solidify when dried or terminated. The clay show a wide scope of water content inside which they are profoundly plastic, from a base water content where the clay is sufficiently clammy to form, to a most extreme water content where the formed clay is sufficiently dry to hold its shape [12].

Owning the previous study which has been scare of mixture of admixture along with clay – concrete, the author has made an attempt to fabricate clay based hybrid concrete with mixture of different admixture in particular required percentages. The prepared hybrids concrete have been subjected for structural and mechanical studies.

2. Materials and Methods

2.1 Materials

The entire admixtures used for the concrete structural study were industrial grade. The Polycarboxylate Ether superplasticizer with purity 98% and density 1.1 g/ml and Sodium lignosulfonate, purity 99 % with density 0.5g/ cm³ supplied by Chemipol Pvt Ltd, Kothari Group of Industries, India. The bonding agent Styrene – butadiene rubber which has the strength from 500 – 3,000 PSI and elongation is about 635% and water soluble Silane compound were procured from Mayfare Biotech Pvt Ltd, Mumbai, India. The bentonite clay with purity 95% and loose density 800 g/l were purchased from Cementation India Pvt. Ltd, India.

2.2 Chemical composition

Table 1: shows the amount of admixture added in clay mixed concrete motor

Sample name	Polycarboxylates	SBR (Bonding agent)	Silane	Sodium lignosulfonate
C-0	1.6 wt %	1.5 % by w/c ratio	0.5 wt %	1 wt %
C-1	1.6 wt %	1.5 % by w/c ratio	0.5 wt %	1 wt %
C-2	1.6 wt %	1.5 % by w/c ratio	0.5 wt %	1 wt %
C-3	1.6 wt %	1.5 % by w/c ratio	0.5 wt %	1 wt %

2.3 Preparation of reinforced concrete

A total of 10 mortar road were cast for two different mix ratios and three different percentage polymer dosages. The mortar mixtures were proportioned with cement to sand ratio of 1:3 and 1:4. The reinforced concretes were cast for the same flow level but different percentages of clay (0 (C0), 5 (C1), 10 (C2) & 15 (C3) wt %) dosage [13]. Three mortar slabs along with admixture for a mix ratio of 1:3 (Cement: sand) were exposed to direct heat from the sun and, four mortar slabs for each mix ratio of 1:3 and 1:4 (cement: sand) were kept away from direct heat. The shrinkage and cracks were measured using the aid of

measuring scale and use of magnifying lens. The data's were recorded for admixture at 5 hours and drying shrinkage at 3, 7, and 28 days [14].

3. Characterization

The structural analyses of the clay mixed concrete were performed using Fourier transform infrared (FTIR) spectrometer (Thermo-Nicolet 6700) in KBr medium. XRD is used to determine the mineralogical composition of the raw material components as well as qualitative and quantitative phase analysis of multiphase mixtures. The occurrences of minerals in clay were identified by comparing 'd' values. The identification of powdered concrete was performed using X'Pert pro X-ray diffractometer with nickel filter. Diffraction data were obtained by exposing the samples to Cu-Ka X-rays, which has a characteristic wavelength of 1.5414 Å. The diffractograms were recorded in terms of 2θ between 20 and 80 degrees. The morphology of the clay and fly ash based reinforced concrete in the form of powder deposited on glass going to investigated using Philips XL 30 ESEM scanning electron microscope (SEM).

4. Mechanical study

The prepared concrete samples have been subjected for mechanical study using Universal Testing machine (UT – 2080) has loading accuracy well within ±1% with 1000 Kgf load capacity system provided by U-CAN DYNATEX INC, Taiwan Central Science Park, Taiwan.

The two-wave-plate compensator (TWC) technique is introduced for single-point retardation measurements using Birefringence Measurement Systems, Hinds Instruments, India. The resolution of the TWC is shown to be 0.001 nm. TWC enables the measurement of sample retardation with as little as 0.13% errors and thus is more accurate than either the Brace-Köhler or the Sénarmont method.

The test is in conformity with the International standard ASTM-C-143 for slump test. The equipment for the slump test includes a hollow frustum of a cone and a ruler as the measuring device (see Figure 1). The height of the cone is 30 cm. The diameter of the top and bottom of the cone is 10 cm and 20 cm, respectively. The cone is filled with fresh concrete and then lifted vertically. The height difference between the concrete and the cone is the slump value.

5. Results and discussion

Figure 1 shows the FTIR spectra of clay mixed cement concrete with different weight percentages of admixture. In spectra predominant peaks are observed at 417.98 cm^{-1} corresponding to C – H bending of ether, 480.78 cm^{-1} is due to the asymmetry stretching of Si – O - Si, 569.32 cm^{-1} for o- position benzene C – C stretching, 581.67 cm^{-1} C = H bending of butadiene group, 1034.66 cm^{-1} for Si – O bending stretching of clay materials, 1688.98 cm^{-1} for Al – O stretching, 3439.60 for H – O bending and 3742.27 corresponding to Fe – O bending in asymmetry molecules.

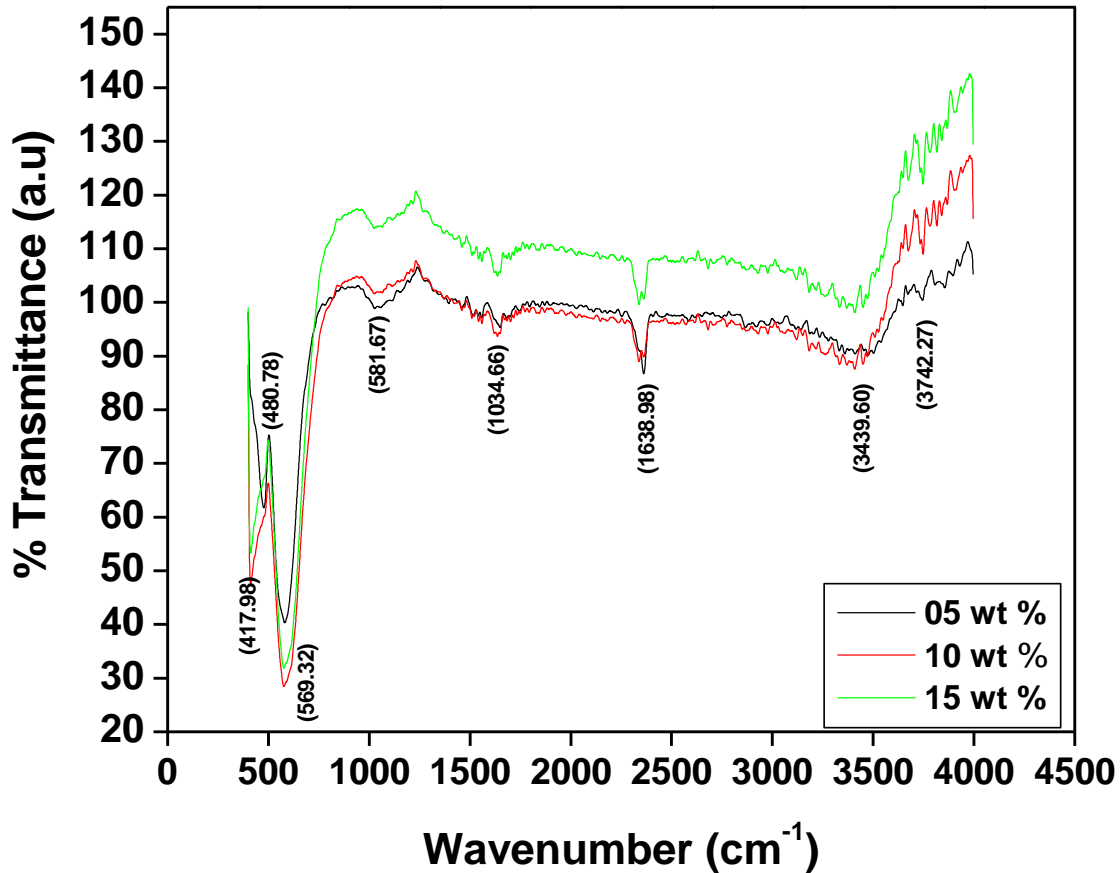


Figure 1 shows that the FTIR spectra of clay mixed concrete with mixture of various weight percentages of admixtures

Figure 2 shows the XRD spectra of the concrete with mixture of various weight percentages of admixtures and C-2 (10 wt %) clay mixed concrete with mixture of various weight percentages of admixtures. It is observed that the angle 2θ value at 12.21° , 15.36° , 21.6° , 29.8° , 33.5° , 34.6° , 35.8° , 36.2° and 42.6° corresponds to (101), (110), (101), (111), (102), (112), (121), (211) and (221) are because of mainly tetrahedrally arranged silicate and octahedrally arrangement of aluminate groups in clay mixed concrete.

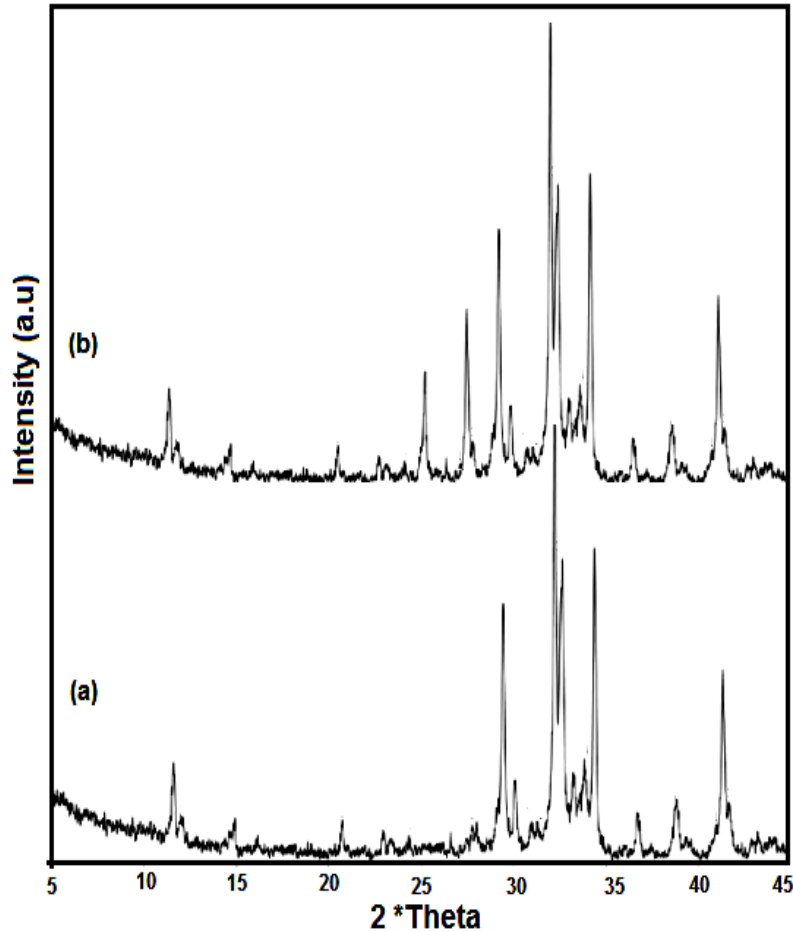


Figure 2 shows that the XRD spectra of (a) concrete with mixture of various weight percentages of admixtures and (b) C-2 (10 wt %) clay mixed concrete with mixture of various weight percentages of admixtures

Figure 3 shows that the SEM image of concrete with mixture of various weight percentages of admixtures and C-2 (10 wt %) clay mixed concrete with mixture of various weight percentages of admixtures. It is observed that the admixture significantly affect the boundary of the clay and cement concrete materials [15]. The image (a) indicates that the clay do not homogeneously mixed with concrete may be due to the indifference surface interaction with the cement materials. However, the presence of polycarboxylate ether and bonding agent SBR agent in the concrete influence the formation of proper mixing without any aggregate as shown in figure (b) [16].

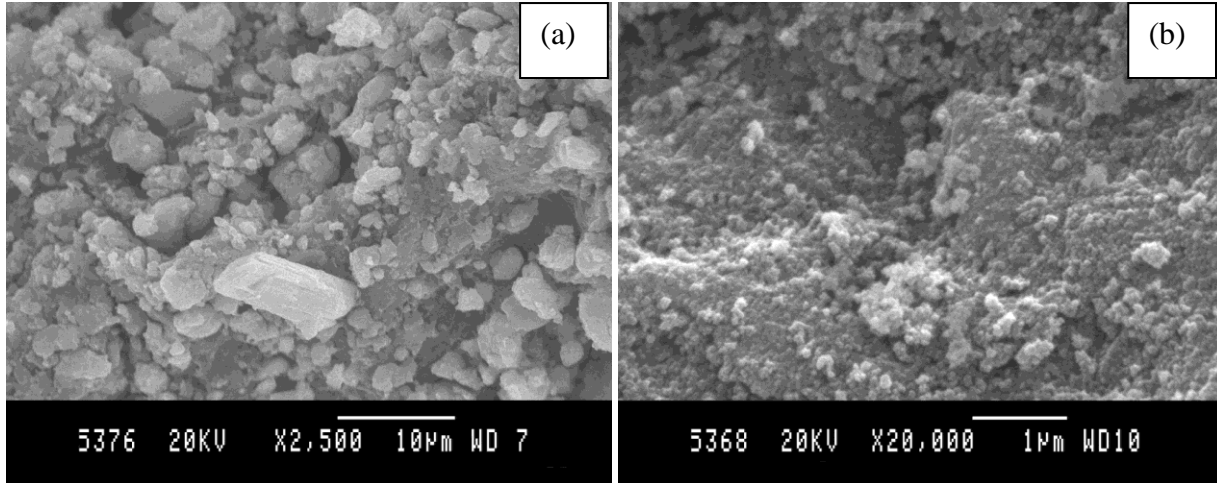


Figure 3 shows that the SEM image of (a) concrete with mixture of various weight percentages of admixtures and (b) C-2 (10 wt %) clay mixed concrete with mixture of various weight percentages of admixtures

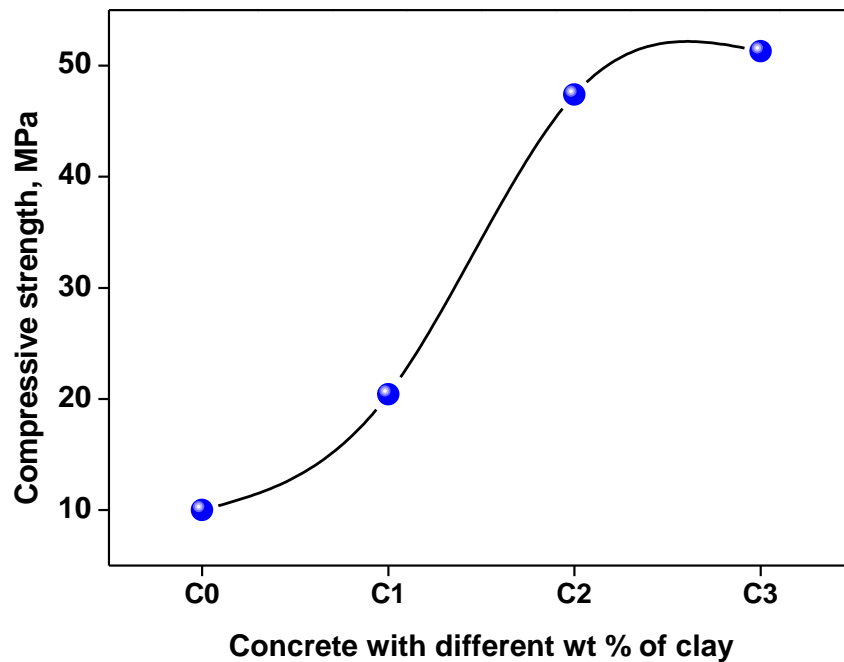


Figure 4 shows that the compressive strength against concrete with different with % of clay prepared with required weight percentage of admixture.

Figure 4 shows that the compressive strength against concrete with different with % of clay prepared with required weight percentage of admixture. It is observed that the compressive strength increases with increase in clay percentages up to C-2 (10 wt %) due to the strong adhesion because of mixture of water

reduce and water repellent which makes better compact and reduce porosity. It is also noted that surface of the block do not having any hair line cracks or honey combs in the concrete structure [17 - 19].

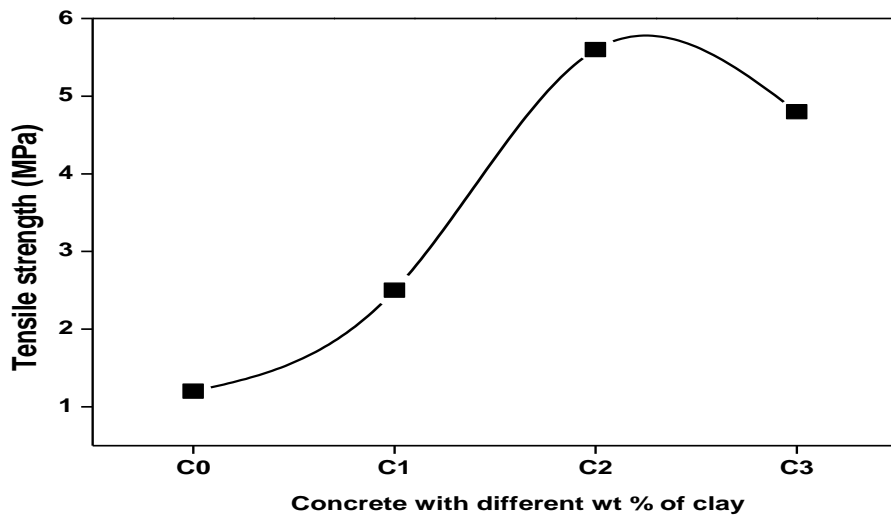


Figure 5 shows that the variation of tensile strength against different weight percentage of clay in concrete with proper ratio of admixture.

Figure 5 shows that the variation of tensile strength against different weight percentage of clay in concrete with proper ratio of admixture. It is found that the tensile strength increases with increase in different weight percentage of clay up to 10 wt % . This is may be due to the high compactness and reduction in porosity of the concrete block. It is also important to note that the water reduce admixture such as Polycarboxylates and Sodium lignosulfonate in required ratio's significantly effects on capillary threshold by reducing 8-12 % of water results higher density of the concrete.

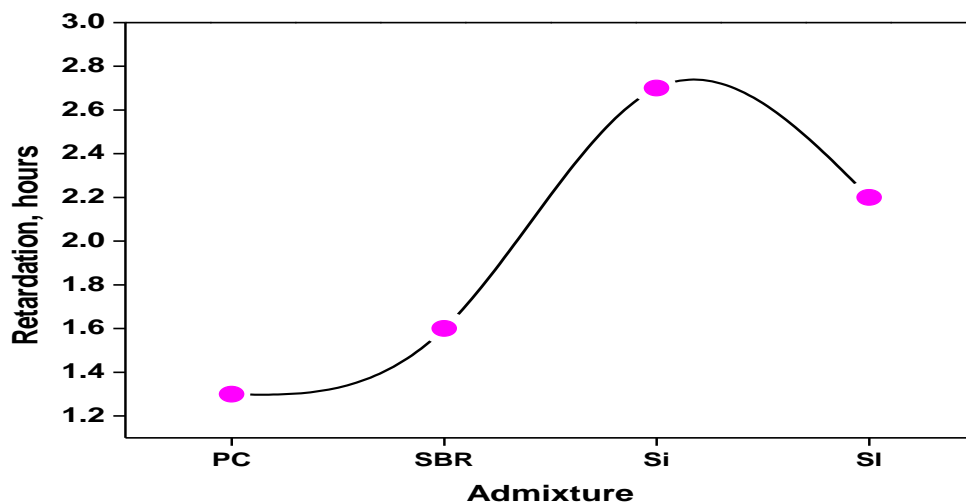


Figure 6 show that the variation retardation of clay mixed concrete with different percentages of admixture.

Figure 6 show that the variation retardation of clay mixed concrete with different percentages of admixture. It is observed that the retardation time increases with increase in clay percentages and silicon weight percentages in concrete. The differences in the water demand affected the hydration products and strength development in these systems. Regarding the microstructure studies, it was revealed that C-S-H and C-A-S-H gels prevail in high calcium and silicon systems, whereas in silicon- and aluminum rich systems (N,C)-A-S-H and C-A-S-H gels predominated [20]. However, the early stage compressive strengths indicated a very promising performance from the application point of view.

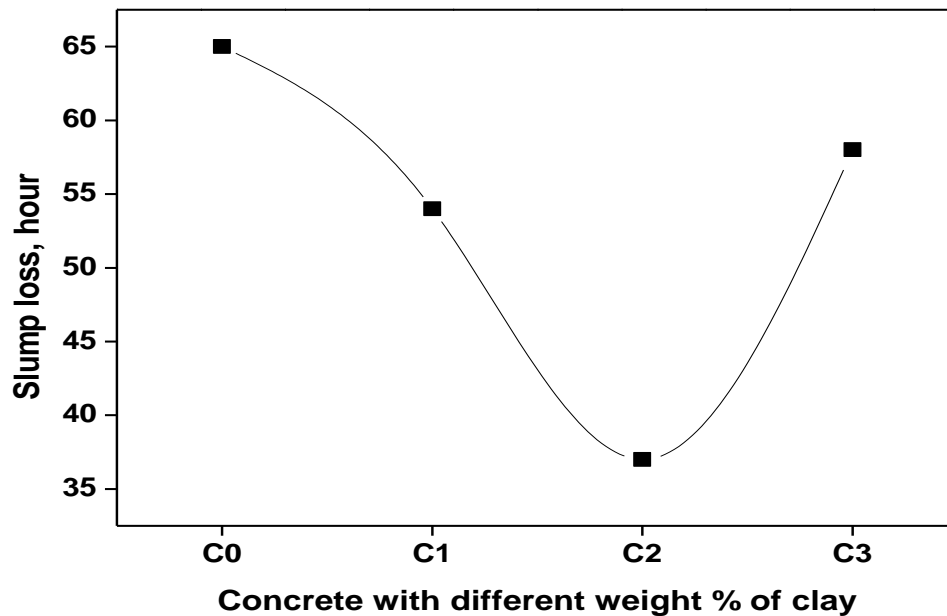


Figure 7 shows that the slump flow increases with increase in different weight percentages of clay mixed concrete within first 2 h.

Figure 7 shows that the slump flow increases with increase in different weight percentages of clay mixed concrete within first 2 h. It could be recognized that the evident workability loss started after the resting time of 25 min. Between 35 min and 65 min, the spread diameter could still reach the value of 300 mm after the table dropped 35 times. However, after 65 min, a notable reduction in flowability was observed, which was likely due to the C-S-H bridges between particles forming a percolated rigid network in the material. This network of interacting particles is still fragile under a relatively high shear force [21]. However, the table dropping process may not be able to supply sufficient shear energy to break all these inter-particle connections.

6. Conclusion

The mortar mixtures have been prepared in various proportioned with cement to sand ratio of 1:3 and 1:4. The reinforced concretes were cast for the same flow level but different percentages of clay (0, 5, 10 & 15%) dosage. The prepared motor concrete subjected for structural study and mechanical property analysis. In FTIR spectra shows predominant peaks are observed at 417.98 cm^{-1} corresponding to C – H bending of ether, 480.78 cm^{-1} is due to the asymmetry stretching of Si – O – Si, 569.32 cm^{-1} for o-position benzene C – C stretching, 581.67 cm^{-1} C = H bending of butadiene group, 1034.66 cm^{-1} for Si –

O bending stretching of clay materials, 1688.98 cm^{-1} for Al – O stretching, 3439.60 for H – O bending and 3742.27 corresponding to Fe – O bending in asymmetry molecules confirms the presence of admixture and clay in the concrete motor. The XRD spectra indicates the formation tetrahedrally arrangement of silicate and octahedrally arrangement of aluminate groups in clay mixed concrete. The surface morphology significantly improved upon adding of different admixture as examined in SEM image. It is found that the presence of polycarboxylate ether and bonding agent SBR agent in the concrete influence the formation of proper mixing without any aggregate. The mechanical study revealed that the compressive strength increases with increase in clay percentages up to C-2 (10 wt %) due to the strong adhesion because of mixture of water reduce and water repellent which makes better compact and reduce porosity. The addition of slump flow improved due to presence of polycarboxylate ether and the evident workability loss started after the resting time of 25 min. Between 35 min and 65 min, the spread diameter could still reach the value of 300 mm after the table dropped 35 times. However, after 65 min, a notable reduction in flowability was observed.

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Authors' contributions

Md Siraj Ahmed has fabricated the hybrid concrete and written the manuscript

Dr.Anil Kunte has constructed the manuscript and analysis the results

Dr.Aashis S Roy has helped in characterization of the hybrid concrete

7. Reference

- [1]. K. Scrivener, F. Martirena, S. Bishnoi, S. Maity, Calcined clay limestone cements (LC3), *Cem. Concr. Res.* 114 (2018) 49–56.
- [2]. W. Huang, H. Kazemi-Kamyab, W. Sun, K. Scrivener, Effect of replacement of silica fume with calcined clay on the hydration and microstructural development of eco-UHPFRC, *Mater. Des.* 121 (2017) 36–46.
- [3]. Y. Dhandapani, M. Santhanam, Assessment of pore structure evolution in the limestone calcined clay cementitious system and its implications for performance, *Cem. Concr. Compos.* 84 (2017) 36–47
- [4]. F. Avet, K. Scrivener, Investigation of the calcined kaolinite content on the hydration of Limestone Calcined Clay Cement (LC3), *Cem. Concr. Res.* 107 (2018) 124–135.

- [5]. N. Roussel, G. Ovarlez, S. Garrault, C. Brumaud, The origins of thixotropy of fresh cement pastes, *Cem. Concr. Res.* 42 (2012) 148–157
- [6]. H. Huang, G. Ye, C. Qian, E. Schlangen, Self-healing in cementitious materials: materials, methods and service conditions, *Mater. Des.* 92 (2016) 499–511
- [7]. M. S ahmaran, V.C. Li, Durability properties of micro-cracked ECC containing high volumes fly ash, *Cem. Concr. Res.* 39 (11) (2009) 1033–1043.
- [8]. Y. Zhao, J. Fickert, K. Landfester, D. Crespy, Encapsulation of self-healing agents in polymer nanocapsules, *Small* 8 (19) (2012) 2954–2958.
- [9]. JS González, FL Gayarre, CLC Pérez, PS Ros, MAS López. Influence of recycled brick aggregates on properties of structural concrete for manufacturing precast prestressed beams. *Constr Build Mater* 149 (2017) 507–14.
- [10]. .E. Oti, J.M. Kinuthia, J. Bai “Engineering properties of unfired clay masonry bricks” *Eng. Geol.*, 107 (2009) 130-139
- [11]. D. Herzog, V. Seyda, E. Wycisk, C. Emmelmann, Additive manufacturing of metals, *Acta Materialia* 117 (2016) 371–392.
- [12]. M. Cappellari, A. Daubresse, and M. Chaouche, “Influence of organic thickening admixtures on the rheological properties of mortars: relationship with water-retention,” *Construction and Building Materials*, 38 (2013) 950–961.
- [13]. FM Khalaf, AS DeVenny. Properties of new and recycled clay brick aggregates for use in concrete. *J Mater Civ Eng* 17 (2005) 456–64.
- [14]. A.Hendi, H. Rahmani, D.Mostofinejad, A. Tavakolinia, and M. Khosravi, “Simultaneous effects of microsilica and nanosilica on self-consolidating concrete in a sulfuric acid medium,” *Construction and Building Materials*, 152 (2017) 192–205
- [15]. X Liu, Z Wang, Y Zheng, S Cui, M Lan, H Li, X Liang, Preparation, characterization and performances of powdered polycarboxylate superplasticizer with bulk polymerization. *Materials*, 7 (2014). 6169-6183
- [16]. R. A. Ibragimov and S. I. Pimenov, “Influence of mechanochemical activation on the cement hydration features,” *Magazine of Civil Engineering*, 62, (2016) 3–12.
- [17]. D. Liu, B. Šavija, G.E. Smith, P.E.J. Flewitt, T. Lowe, E. Schlangen, Towards understanding the influence of porosity on mechanical and fracture behaviour of quasi-brittle materials: experiments and modelling, *Int. J. Fract.* 205 (2017) 57–72.
- [18]. K. S. Al-Jabri, M. Hisada, S. K. Al-Oraimi, and A. H. Al- Saidy, “Copper slag as sand replacement for high performance concrete,” *Cement and Concrete Composites*, 31, (2009) 483–488
- [19]. A. Heath, P. Walker, C. Fourie, M. Lawrence “Compressive strength of extruded unfired clay masonry units” *Proc Inst Civ Eng Constr Mater*, 162 (2009) 105-112,
- [20]. PB Cachim. Mechanical properties of brick aggregate concrete. *Constr Build Mater* 23 (2009) 1292–7
- [21]. Ş Erdoğdu, Effect of retempering with superplasticizer admixtures on slump loss and compressive strength of concrete subjected to prolonged mixing. *Cement and Concrete Research*, 35(5), (2005) 907-912

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