Early Age Properties of Zeolite Cementitious Materials

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Background

- Between 900 to 1000 kg of CO_2 emissions for producing every 1000 kg of portland cement [1].
- Use of supplementary cementitious materials (SCMs) as the replacement of portland cement can lower the CO_2 emissions & also have other environmental benefits.
- Need to make durable concrete structures for reducing service cost using relatively cheap SCMs.

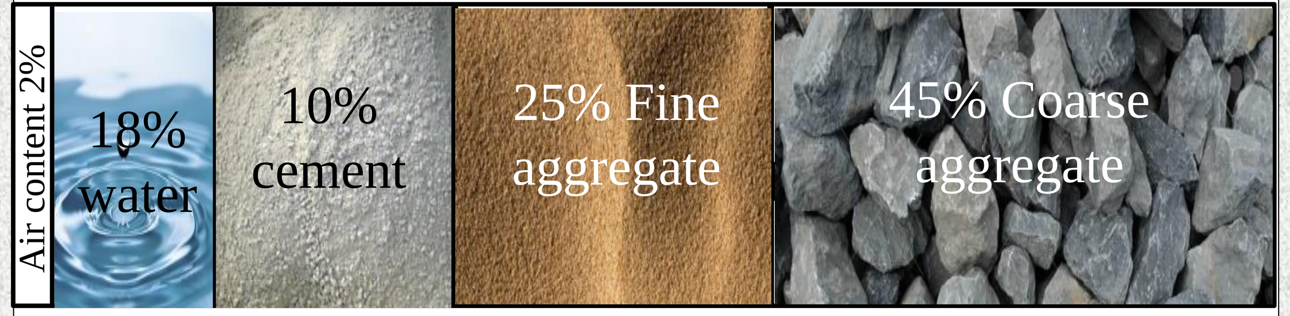

Fig. 1. Typical concrete make up without SCMs.

About Zeolite

Fig. 2. Natural zeolite

- Clinoptilolite content of zeolite is a natural pozzolans having 97% purity.
- Hydrated alumina-silica based minerals with surface area of 35-45 m^2/g and specific gravity is 1.89.
- Good cation exchange capacity without changing its properties.
- Increase durability properties of concrete against sulfate attack, alkali silica reaction, shrinkages, etc. [2-3].
- Relatively cheap & available, using benefit outweigh the costs.

Oxides of cement and zeolite

Oxide (%)	Portland cement	Natural zeolite
SiO_2	18.94	66.7
Al_2O_3	5.65	11.48
Fe_2O_3	3.29	0.90
CaO	63.20	1.33
MgO	3.13	0.22
Na_2O	0.34	1.80
K_2O	0.78	3.42
MnO	N/A	0.025
SO_3	3.43	0.52

Objective of study

- To determine the early age properties of zeolite blended cementitious paste i.e. workability, setting time and heat of hydration.
- Applicability of using natural zeolite as SCM with the replacement of cement for producing durable concrete.

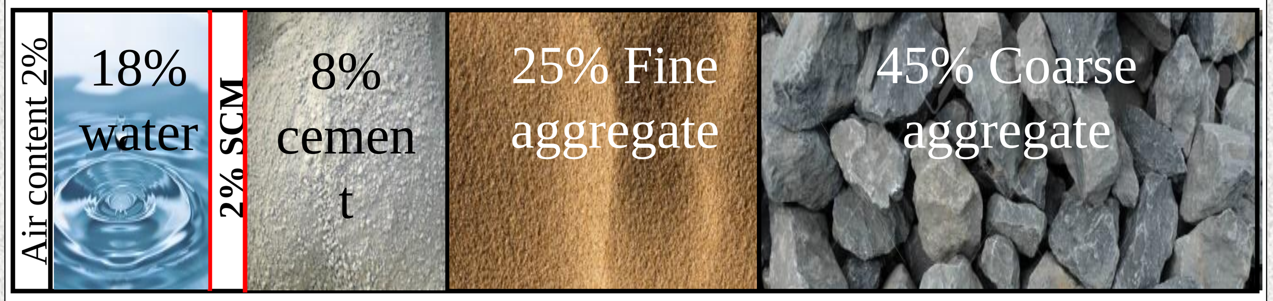

Fig. 3. Typical concrete make up with SCMs.

Methodology

Natural zeolite replaced portland cement at 0, 5, 10, 15, and 20% by mass namely Control, NZ 5, NZ 10, NZ 15, NZ 20 respectively.

- For measuring workability, mortar was prepared without chemical admixtures with a water-to-cementitious materials (w/cm) ratio of 0.485 according to ASTM C 109 and tested as per ASTM C 1437.

Fig. 4. Flow table.

Fig. 5. Flow table value.

- For measuring setting time, cementitious paste was made with w/cm ratio = 0.40. An automatic Vicat apparatus machine having 1 mm penetration needle was used with 10 mins of penetration interval to accomplish the test method B by ASTM C191-18a.

Fig. 6. Vicat apparatus.

Fig. 7. Samples after testing.

- Samples were prepared with w/cm ratio of 0.45 and placed in sealed glass vials for monitoring at least 72 hours at 25 ^{0}C in a TAM Air isothermal calorimeter. Heat of hydration calculations were done according to ASTM C1679-17.

Fig. 8. Mixing paste.

Fig. 9. Isothermal Calorimeter.

Research Results

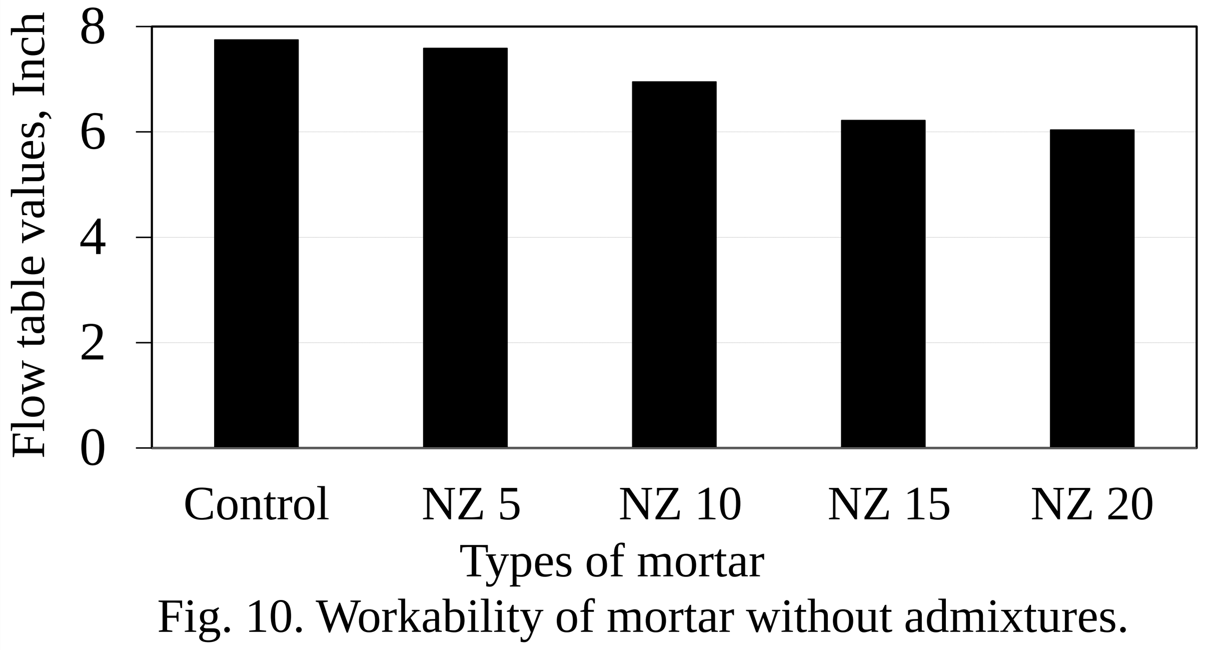

Fig. 10. Workability of mortar without admixtures.

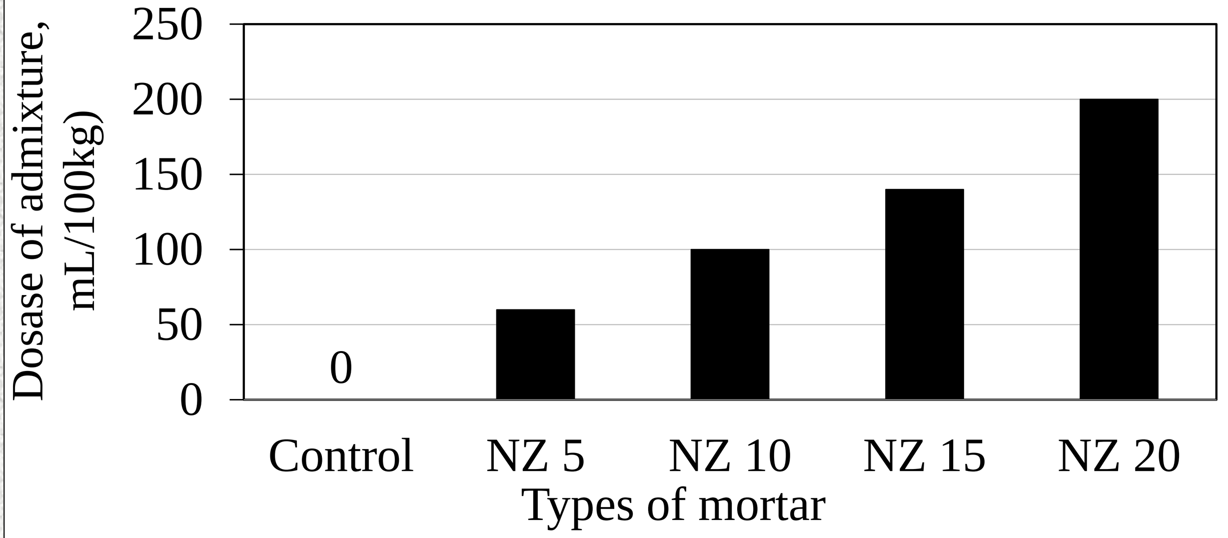

Fig. 11. Dosages of high range water reducing admixtures to maintain constant workability.

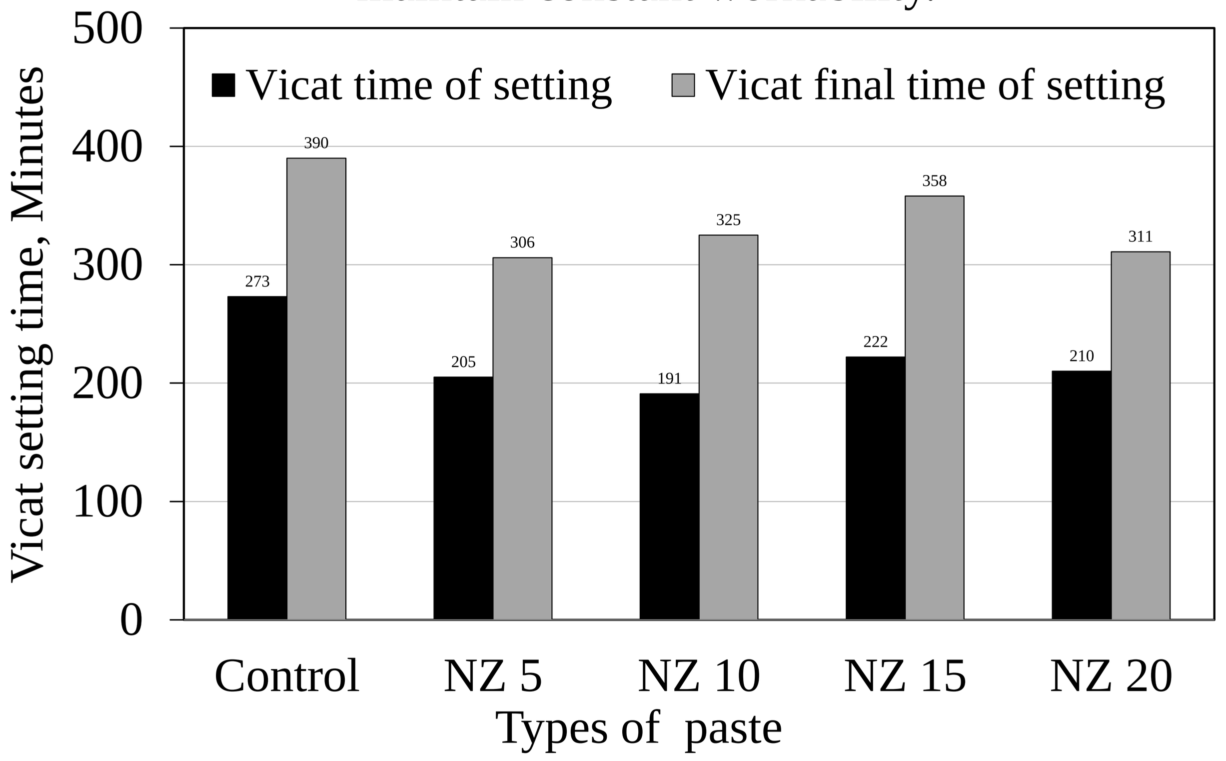

Fig. 12. Initial & final Setting time of cementitious pastes.

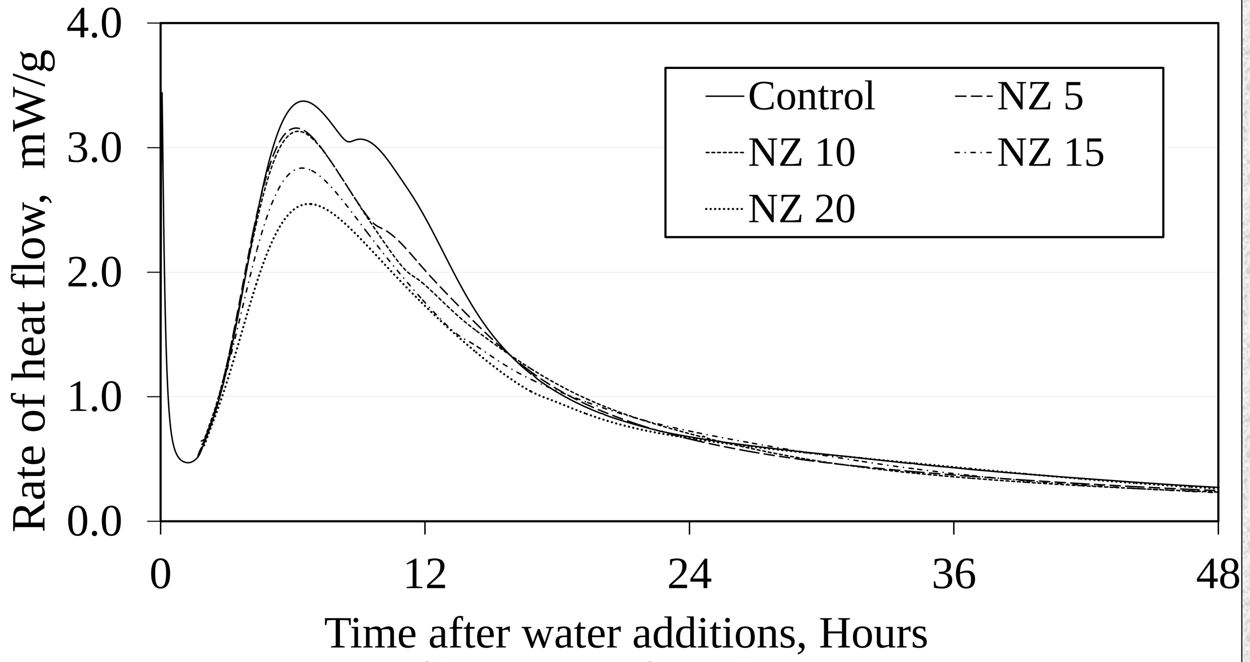

Fig. 13. Heat of hydration for all cementitious pastes

Conclusion

- According to Fig. 10, water demand for workability was relatively high for mortar made with 5%-20% zeolite compared to control case. Use of up to 20% zeolite in the cementitious mortar, can reduce the workability of up to 10 to 20% due to higher surface area of zeolite particles.
- Using very little dosages of high range water reducing admixtures, workability of zeolite samples can be made same as like as control case without segregation as shown in Fig. 11.
- As per Fig. 12, replacement of portland cement with zeolite (5-20% by mass) can reduce the initial setting time by 50-80 mins and final setting time by 30-80 minutes of cementitious pastes. Zeolite can accelerate the setting time of pastes due to nucleation sites effects on C-S-H precipitation.
- Fig. 13 showed 5-20% zeolite blended samples produced 7 to 25% lower peak rate of heat of hydration compared to control case in 48 hours. It was due to slow chemical dissolution and adsorption of water by the zeolite surface. Additionally, tricalcium aluminate (C_3A) peak decreases with the increasing amount of zeolite.

Future studies

- ✓ A detailed investigation will be conducting on the durability properties of zeolite cementitious materials i.e. alkali-silica reaction, chemical shrinkage, drying shrinkage, autogenous shrinkage, compressive strength.
- ✓ Additionally, finding out the factors that influence the modification of its properties by cation exchange, acid treatment, or calcination.

References

[1] EPA (Environmental Protection Agency). (2005). "Compilation of Air Pollutant Emission Factors: Stationary Point and Area Sources." Volume I, Washington, DC, 2005.

[2] Najimi, M., Sobhani, J., Ahmadi, B., and Shekarchi, M. "An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan." *Constr. Build. Mater.*, 35, pp. 1023-1033, 2012.

[3] Markiv, T., Sobol, k., Franus, M., and Franus, W. "Mechanical and durability properties of concretes incorporating natural zeolite." *Arc. Civil and Mech. Eng.*, 16 554-562, 2016.