Effect of Zeolite on the Compressive Strength and Durability Properties of Roller Compacted Mass Concrete

Ali Sarafi[1], Seyed Mehdi Zahrai[2*], Amir Mohammad Ramezanianpour[3]

[1] M.Sc. in Structural Engineering, School of Civil Engineering, University of Tehran

[2*] Professor, School of Civil Engineering, College of Engineering, University of Tehran

[3] Associate Professor, School of Civil Engineering, University of Tehran

ABSTRACT

Roller Compacted Mass Concrete is one of the special types of concrete that has a low amount of cement in its mixture proportion in order to reduce the heat caused by the hydration reaction. This increases the permeability of roller compacted concrete compared to conventional concrete. The increase in permeability also leads to the entry of destructive ions into concrete of mass structures and ultimately the instability of these structures. Supplementary cementitious materials such as zeolite can reduce permeability, so in this research, the effect of replacing a part of cement with zeolite on durability and mechanical properties of roller compacted concrete has been investigated. First, chemical analysis and pozzolanic activity of zeolite were investigated. Then, in order to evaluate the effect of zeolite on the properties of concrete, roller compacted concrete specimens were made in four mixture proportions with replacement percentages of 0%, 15%, 30% and 40% of cement with zeolite and subjected to compressive strength, water penetration depth, water absorption, Rapid Chloride Permeability Test (RCPT), electrical resistivity, Ultrasonic Pulse Velocity (UPV). The workability of the roller compacted concrete mixtures was also determined by the V.B. time test. The results showed that according to RCPT, water penetration depth and electrical resistivity tests, replacing 15% of cement weight with zeolite reduces permeability and significantly improves durability properties of roller compacted concrete. Also, increasing the percentage of zeolite reduces the compressive strength of the specimens.

KEYWORDS

Zeolite, Roller-Compacted Concrete (RCC), Durability Properties, Mechanical Properties, Workability.

* Corresponding Author: Email: mzahrai@ut.ac.ir

1. Introduction

Roller compacted mass concrete (RCC) is a type of concrete with zero slump that consists mostly of aggregates, this leads to higher permeability of RCC compared to conventional concrete, as the cement paste cannot completely fill the voids between the aggregates. One of the ways to improve the properties of concrete is to replace a part of cement with supplementary cementitious materials. This strategy could be applied to RCC as well. In recent years, researchers confirmed the positive effect of supplementary cementitious materials on improving the durability and compressive strength of RCC by using pozzolans such as silica fume, nanosilica, metakaolin, fly ash and slag to the concrete paste [1-5].

As an SCM, natural zeolite is a hydrated aluminosilicate of alkali and alkaline earth cations that, due to the presence of large amounts of aluminum oxide and active silica in its chemical composition, can react well with calcium hydroxide resulting from hydration and improve the properties of concrete [6]. Researchers replaced part of cement with zeolite in conventional concrete and their experimental conclusion confirmed the effectiveness of zeolite in improving the durability and mechanical properties of conventional concrete [7-9].

Several studies have been conducted on improving properties of conventional concrete by replacing part of cement with zeolite but no study has been conducted about effect of zeolite on the durability and mechanical properties of Roller compacted mass concrete. Therefore, in this study, RCC specimens containing replacement levels of 0%, 15%, 30%, and 40% by zeolite were made. The specimens were used for compressive strength test, rapid chloride permeability test, water penetration depth, water absorption, ultrasonic pulse velocity and electrical resistivity. Also, V.B. time and specific weight tests were conducted on concrete mixtures.

2. Methodology

In this study, 4 mixture proportions of RCC containing various contents of zeolite, namely 0%, 15%, 30% and 40% of the weight of Portland cement were considered. In order to make concrete mixtures, fine and coarse aggregates, cement and zeolite were dry mixed, then water was added to the concrete mixture. From the time of adding water to the mixture, the materials were mixed for 4 minutes. The mixture proportions are presented in Table 1.

Table 4. Mixture proportions

Mixture marking	W/b	Cement (kg/m^3)	Zeolite (kg/m^3)	Water (kg/m^3)	Coarse gravel (kg/m^3)	Fine gravel (kg/m^3)	Sand (kg/m^3)
Z0	0.72	208	0	151	513.75	513.75	1027.5
Z15	0.72	176.8	31.2	151	513.75	513.75	1027.5
Z30	0.72	145.6	62.4	151	513.75	513.75	1027.5
Z40	0.72	124.8	83.2	151	513.75	513.75	1027.5

2.1. Pozzolanic activity index test

Pozzolanic activity index test was conducted according to ASTM C311.

2.2. V.B. time test

The V.B. time test was conducted according to ASTM C1170 for evaluating the workability of RCC mixtures.

2.3. Compressive strength

The compressive strength test was conducted according to ASTM C39.

2.4. Rapid chloride permeability test (RCPT)

Rapid chloride permeability test was conducted according to ASTM C1202. Specimens were placed in contact with a cell, one filled with NaCl solution and the other filled with NaOH solution. After that, a 60 V potential difference was applied across the two ends of cores for 6 hours.

2.5. Water penetration depth in concrete

Water penetration depth test was conducted in accordance with EN 12390-8.

2.6. Water absorption

Water absorption test was conducted according to ASTM C642.

2.7. Fresh concrete specific weight

The fresh concrete specific weight test of fresh concrete was conducted according to ASTM C138.

2.8. Ultrasonic pulse velocity (UPV)

This experiment was conducted according to ASTM C597.

2.9. Electrical resistivity

The electrical resistivity was measured in kΩ-cm.

3. Result Discussion

3.1. Pozzolanic activity index

According to the results obtained from this experiment, the pozzolanic activity index of zeolite is 96.2%. These results show that the pozzolanic activity of zeolite at early ages (7 days) was less than the hydration reaction of Portland cement, but almost equal to it at 28 days.

3.2. V.B. time

Replacing 15%, 30% and 40% of cement with zeolite in the RCC mixtures resulted in 25%, 31%, and 47% decrease in the VB time, respectively.

3.3. Compressive strength

According to 7-day compressive strength results, replacing 15%, 30%, and 40% cement with zeolite has decreased the compressive strength by 45.7%, 56%, and 61.7% respectively. This amount of reduction for 28-day compressive strength is 24.7%, 39.5% and 51.6% respectively, for 56-day results 27%, 34.3% and 46.1% respectively and for 91-day results is 21.2%, 35.3% and 45.3%.

3.4. Rapid chloride permeability test (RCPT)

The charge passed through the 15% zeolite containing specimens was 29.4% lower than that of control specimen. The reason for this is the desirable properties of zeolite, such as the appropriate pozzolanic reaction at the testing age (28 days) and its filling property.

3.5. Water penetration depth

Replacing 15% of cement weight with zeolite has decreased the water penetration depth by 13%.

3.6. Water absorption

Replacing 15% of cement weight with zeolite resulted in 3.84%, 4.1% and 20.5% increase in the 0.5, 1- and 24-hours water absorption, respectively.

3.7. Specific weight of fresh concrete

Replacing 15%, 30% and 40% of cement weight with zeolite has increased specific weight by 2.9%, 4.5% and 5.5%, respectively.

3.8. Ultrasonic pulse velocity

Replacing 15% of the cement weight with zeolite slightly decreased the ultrasonic pulse velocity.

3.9. Electrical resistivity

Replacing 15% of cement weight with zeolite increased the electrical resistivity of concrete by 151.5%.

4. Conclusions

- For 7-, 28-, 56- and 91-day ages, increasing the replacement level of zeolite decreased the compressive strength of mixtures.

- The results of RCPT, water penetration depth, and electrical resistivity tests showed that natural zeolite had a significant effect on reducing the permeability and improving the durability properties of RCC.

References

[1] A. Mardani-Aghabaglou, Ö. Andiç-Çakir, K. Ramyar, Freeze–thaw resistance and transport properties of high-volume fly ash roller compacted concrete designed by maximum density method, Cement and Concrete Composites, 37 (2013) 259-266.
[2] L. Shen, Q. Li, W. Ge, S. Xu, The mechanical property and frost resistance of roller compacted concrete by mixing silica fume and limestone powder: Experimental study, Construction and Building Materials, 239 (2020) 117882.
[3] P. Duan, Z. Shui, W. Chen, C. Shen, Effects of metakaolin, silica fume and slag on pore structure, interfacial transition zone and compressive strength of concrete, Construction and Building Materials, 44 (2013) 1-6.
[4] P. Ghoddousi, L. Adelzade Saadabadi, Effect of Pore Physical and Chemical Microstructure Properties on Durability and Rebar Corrosion of Self-Compacting Concretes Containing Silica Fume and Metakaolin, Journal of Materials in Civil Engineering, 34(12) (2022) 04022330.
[5] D. Tavakoli, R.S. Dehkordi, H. Divandari, J. de Brito, Properties of roller-compacted concrete pavement containing waste aggregates and nano SiO2, Construction and Building Materials, 249 (2020) 118747.
[6] B. Ahmadi, M. Shekarchi, Use of natural zeolite as a supplementary cementitious material, Cement and concrete composites, 32(2) (2010) 134-141.
[7] M. Valipour, F. Pargar, M. Shekarchi, S. Khani, Comparing a natural pozzolan, zeolite, to metakaolin and silica fume in terms of their effect on the durability characteristics of concrete: A laboratory study, Construction and Building Materials, 41 (2013) 879-888.
[8] M. Najimi, J. Sobhani, B. Ahmadi, M. Shekarchi, An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan, Construction and building materials, 35 (2012) 1023-1033.
[9] A.A. Ramezanianpour, R. Mousavi, M. Kalhori, J. Sobhani, M. Najimi, Micro and macro level properties of natural zeolite contained concretes, Construction and building materials, 101 (2015) 347-358.