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Research Article

Addition of Ground Zeolite to Improve the Flowability and Cohesiveness of Mortar

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Abstract

Packing density if of cardinal importantce in the performance of cement-based materials. Theoretically, ground zeolite (GZ), a cementitious material that is finer than cement and coarser than condensed silica fume (CSF), is able to fill the voids between the cement particles in mortar for performance improvement without excessively high specific surface area. In order to evaluate the effects of GZ on flowability and cohesiveness, a total of 15 mortar mixes with different GZ contents and different cementitious materials/aggregate ratios at the same water/cementitious materials ratio were produced for flowability, cohesiveness and strength measurement. Results indicated that adding GZ as no more than 5% cement replacement would increase the flowability and strength, but further addition of GZ to more than 5% decreased the flowability, cohesiveness and strength. The experimental results are in general agreement with the findings from the literatures. Adding GZ tas no more than 5% cement replacement improve both the flowability and cohesiveness at equal-strength basis, further addition of GZ upon 5% improved the concurrent flowability and strength performance when the strength requirement is low, but impaired the concurrent cohesiveness and strength performance. It can be concluded that 5% is optimum GZ addition content in the viewpoint of flowability and cohesiveness performance of mortar.

Keywords

Cohesiveness, Flowability, Zeolite

1. Introduction

Ground zeolite (GZ) is a cementitious material that is finer than cement and coarser than condensed silica fume (CSF). Its use in mortar or concrete could improve the packing density and avoid excessively high specific surface area. On the use of zeolite in mortar concrete, Ahmadi and Shekarchi observed that the effectiveness in mitigating ASR increased with the amount of GZ added [1]. Najimi *et al.* showed that partial replacement of cement with GZ could reduce the chloride ion penetration, water penetration, and drying shrinkage [2]. Dousti *et al.* showed that GZ was effective but not as good as CSF in improving the chloride resistance [3]. Valipour *et al.* concluded that although GZ was not as reactive as CSF or metakaolin, it could be used as a more economical and environmentally friendly substitute of CSF or metakaolin [4]. Ranjbar *et al.* demonstrated that GZ is particularly good for production of self-consolidating concrete [5]. Hailu *et al.* advocated that zeolite was abl to participate on the hardness removal [6]. Vejmelková *et al.* found that the addition of not more than 20% GZ to replace cement only slightly reduced the compressive strength, bending strength,

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fracture toughness and specific fracture energy of the concrete [7]. Ramezanianpour *et al.* reported that the use of GZ increased the water demand, slightly decreased or had little effect on the strength and significantly reduced the water permeability and capillary absorption [8].

Markiv *et al.* revealed that adding GZ as cement replacement would increase the SP demand, but with SP added, could reduce the water penetration and drying shrinkage and improve the freeze-thaw resistance [9]. Nagrockienė and Girskasshowed that substitution of up to 10% of cement with GZ would increase the strength, density and ultrasonic pulse velocity, and reduce the water absorption [10]. Nagrockienė *et al.* observed that the addition of GZ increased the ultrasonic pulse velocity, reduced the water absorption and increased the freeze-thaw resistance [11]. Tran *et al.* accentuates a great potential of natural zeolites as additives to concrete in which they can greatly improve the mechanical properties and durability while helping reduce its permeability [12]. Recently, Kumar *et al.* pointed out that 15% of the binder was the optimum zeolite content for maximum compressive strength, maximum flexural strength and maximum split strength [13]. Zheng *et al.* demonstrated that sulfate-zeolite addition enhanced the hydration degree of cement and consequently the compressive strength [14]. To conclude from the previous studies, GZ has been proven to be an effective pozzolanic material for replacing part of the cement. Up to now, there is little systematic study on the effect of zeolite for cohesiveness and flowability performance at various cementitious materials/aggregate ratio. To fill this gap, a systematic experimental study was launched, as reported herein.

2. Experimental Program

The performance of the mortar at both fresh and hardened status containing different contents of GZ and at different cementitious materials/aggregate ratios were measured. The water/cementitious materials ratio was set constant as 1.40 for all the mortar mixtures. The GZ content, expressed as a volumetric ratio of the whole cementitious material content, changed from 0 to 20% in increments of 5%. The cementitious materials/aggregate ratios were 0.55, 0.65 and 0.75.

3. Materials

In this study, ordinary Portland cement of strength class 42.5N was used. The standard sand adopted in strength determination of cement was adopted as fine aggregate. The cement, zeolite and standard sand meet the requirement of EN 197: Part 1: 2011, ASTM C618 and ISO 679: 2009, respectively. The SP adopted was polycarboxylate one. It was featured by a backbone chain and side chains. The particle size conditions of the raw materials were determined through laser diffraction method. The results are presented in Figure 1. It showes that the GZ owned a wider size range than cement.

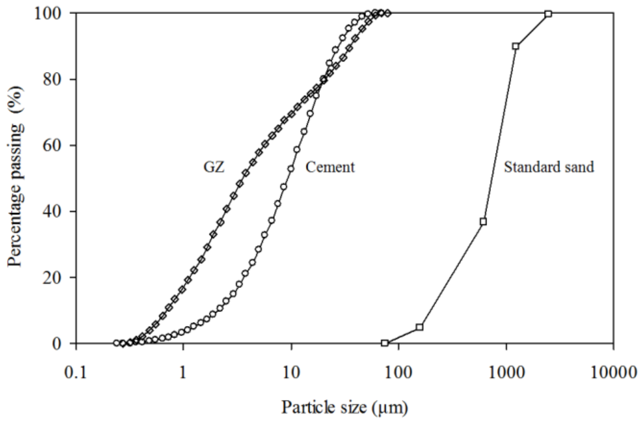

Figure 1. *Particle size distributions.*

The superplasticizer used in this study was a third generation polycarboxylate-based one. It was an aqueous solution with a solid mass content and a relative density of 20% and 1.03, respectively. Basically, its molecular structure can be characterized by an active-monomer formed main chain attached with graft copolymers formed side chains. Compared to the earlier generation superplasticizers, this kind of superplasticizer is more effective as it can disperse fine particles by not only electrostatic repulsion and but also steric repulsion.

4. Test Method

4.1. Flowability

A Marsh cone test was applied for flowability measurement. The flowability, represented by the flow rate, was determined as the average rate of the mix flowing out from Marsh cone. The flow rate was expressed as volume per time.

4.2. Cohesiveness

Sieve segregation method was applied for cohesiveness measurement. The aperture size of the sieve was 1.25 mm.

4.3. Strength

28-day age 100 mm cubes were applied for compressive strength measurement.

5. Experimental Results

5.1. Flowability

To study the effect of GZ on flowability, the results are displared versus the cementitious materials ratio/aggregate ratio for various GZ contents in Figure 2. Increasing the cementitious materials ratio/aggregate ratio enhanced the flowability. On the other hand, at the same cementitious materials ratio/aggregate ratio, adding GZ as no more than 5% cement replacement improved the flowability, while addition of GZ to beyond 5% decreased the flowability. It can be concluded that the addition of GZ would, depending on the addition content, increase or decrease the flowability. This is in agreement with the results from Markiv *et al.* [9], who reported that GZ was not necessarily benefical to the flowability.

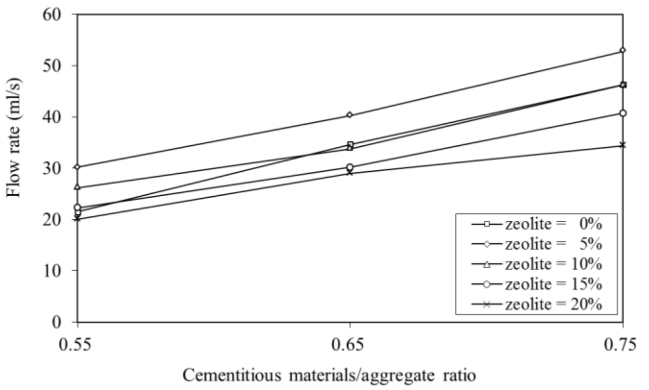

Figure 2. *Flowability of GZ mortar mixes at various cementitious materials/aggregate ratio.*

5.2. Cohesiveness

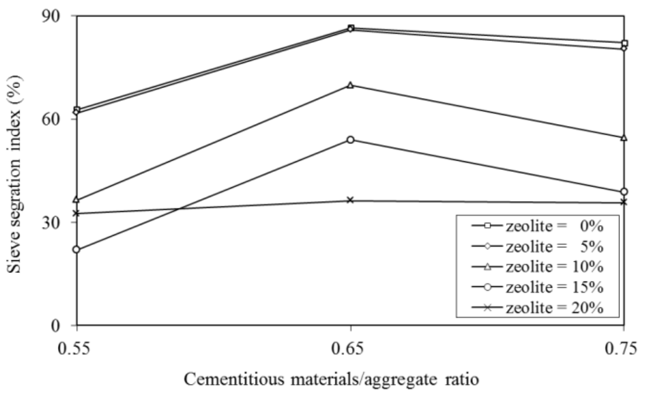

Figure 3. *Cohesiveness of GZ mortar mixes at various cementitious materials/aggregate ratio.*

To study the effect of GZ on cohesiveness, the sieve segregation index results are displared versus the cementitious materials ratio/aggregate ratio for various GZ contents in Figure 3. As revealed by the sieve segregation index curves in the figure, an increase of cementitious materials/aggregate ratio enhanced the SSI, while higher cementitious materials/aggregate ratio lowered the SSI. On the other hand, adding GZ as no more than 5% cement replacement had little effect on the sieve segregation index. To interpret the SSI results, a higher SSI resulted in a lower cohesiveness and vice versa. These implied that an increase of cementitious materials/aggregate ratio would, depending on the cementitious materials/aggregate ratio, improve or impair the cohesiveness. Also, the addition of GZ would, depending on the GZ content, change slightly or improve the cohesiveness.

5.3. Strength

To study the effect of GZ on strength, the compressive strength results are displared versus the cementitious materials ratio/aggregate ratio for various GZ contents in Figure 4. As revealed by the strength curves in the figure, an increase of cementitious materials/aggregate ratio enhanced the strength. On the other hand, no more than 5% enhanced the strength, and more than 5% GZ lowered the sterength. This could be explained by the packing density theory.

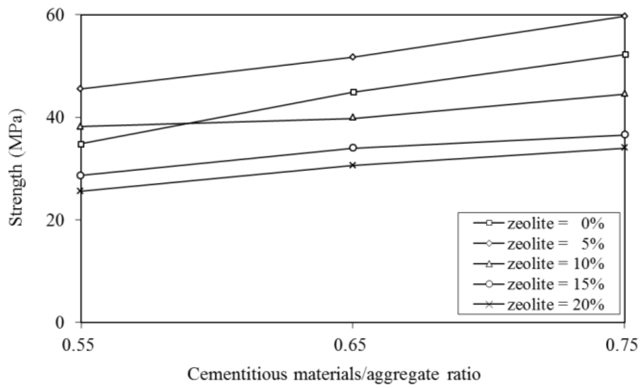

Figure 4. *Strength of GZ mortar mixes at various cementitious materials/aggregate ratio.*

6. Performance on Equal Strength

As strength is a basic requirement for practical structural use, the flowability and cohesiveness performance shall be assessed on the equal-strength basis. To reveal the effect of GZ on the flowability and cohesiveness on equal-strength basis, the concurrent flowability and strength performance and the concurrent cohesiveness and strength performance are presented as follows.

6.1. Flowability

As revealed from the concurrent flowability and strength performance shown in Figure 5, the addition of 5% GZ could increase the both the flowability and the strength at the same time. With 5% GZ added, further addition of GZ would decrease the flowability and the strength at the same time. Since further addition of GZ upon 5% tend to shift the flowability-strength curves to the left side, it hints that further addition of GZ upon 5% may improve the concurrent cohesiveness and strength performance when the strength requirement is low.

It is interesting that both the flowability and the strength could be increased at the same time, which appeared to be contradictory to the general concept that the flowability decreased when the strength increased. This is because the general way to obtain a high strength is to adopt a lower water/cementitious ratio, and then the flowability would be impaired; whereas in this study, the high strength was achieved by adopting a higher paste volume, and then the flowability was increased.

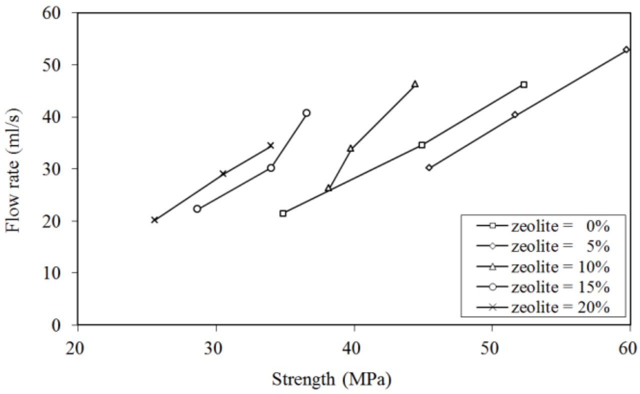

Figure 5. Concurrent flowability and strength performance.

6.2. Cohesiveness

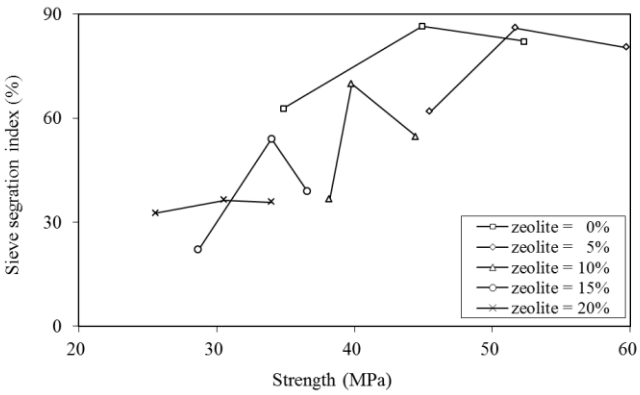

Figure 6. Concurrent cohesiveness and strength performance.

As revealed from the concurrent cohesiveness and strength performance shown in Figure 6, the addition of 5% GZ could increase the strength without significant effect of the cohesiveness. With 5% GZ added, further addition of GZ would decrease the strength and generally increased the cohesiveness. Since further addition of GZ upon 5% tend to shift the cohesiveness-strength curves to the left side, it is indicated that further addition of GZ upon 5% could not improve the concurrent cohesiveness and strength performance.

7. Conclusions

To study the effect of GZ on flowability and cohesiveness performance of mortar, a total of 15 mortar mixes were made for flow rate, SSI and compressive strength measurement. The major findings are summarized as follows:

1. Adding GZ as no more than 5% cement replacement increased the flowability, but further addition of GZ to beyond 5% decreased the flowability.
2. Adding GZ as no more than 5% cement replacement had little effect on the cohesiveness, but further addition of GZ to beyond 5% decreased the cohesiveness.
3. Adding GZas no more than 5% cement replacement increased the strength, but further addition of GZ to beyond 5% decreased the strength.
4. Adding GZ tas no more than 5% cement replacement improve both the flowability and cohesiveness at equal-strength basis, further addition of GZ upon 5% improved the concurrent flowability and strength performance when the strength requirement is low, but impaired the concurrent cohesiveness and strength performance.

Overall speaking, 5% would be optimum GZ addition content in the viewpoint of flowability and cohesiveness performance of mortar.

Abbreviations

CSF	Condensed Silica
GZ	Ground Zeolite

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Author Contributions

Jiajian Chen: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project Administration, Funding Acquisition

Weiliang Xie: Formal Analysis, Writing – review and editing

Tianxiang Chen: Formal Analysis, Writing – review and editing

The authors read and approved the final manuscript

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ahmadi B, Shekarchi M. Use of natural zeolite as a supplementary cementitious material. Cem Concr Compos 2010; 32(2): 134-41. https://doi.org/10.1016/j.cemconcomp.2009.10.006

[2] Najimi M, Sobhani J, Ahmadi B, Shekarchi M. An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan. Constr Build Mater 2012; 35: 1023-33, https://doi.org/10.1016/j.conbuildmat.2012.04.038

[3] Dousti A, Rashetnia R, Ahmadi B, Shekarchi M. Influence of exposure temperature on chloride diffusion in concretes incorporating silica fume or natural zeolite. Constr Build Mater 2013; 49: 393-9, https://doi.org/10.1016/j.conbuildmat.2013.08.086

[4] Valipour M, Pargar F, Shekarchi M, Khani S. Comparing a natural pozzolan, zeolite, to metakaolin and silica fume in terms of their effect on the durability characteristics of concrete: A laboratory study. Constr Build Mater 2013; 41: 879-88, https://doi.org/10.1016/j.conbuildmat.2012.11.054

[5] Ranjbar MM, Madandoust R, Mousavi SY, Yosefi S. Effects of natural zeolite on the fresh and hardened properties of self-compacted concrete. Constr Build Mater 2013; 47: 806-13, https://doi.org/10.1016/j.conbuildmat.2013.05.097

[6] Hailu Y, Tilahun E, Brhane A, Resky H, Sahu O. Ion exchanges process for calcium, magnesium and total hardness from ground water with natural zeolite. Groundwater Sustainable Dev 2019; 8: 457-467, https://doi.org/10.1016/j.gsd.2019.01.009

[7] Vejmelková E, Koňáková D, Kulovaná T, Keppert Martin, Žumár J, Rovnaníková P, Keršner Z, Sedlmajer M, Černý R. Engineering properties of concrete containing natural zeolite as supplementary cementitious material: Strength, toughness, durability, and hygrothermal performance. Cem Concr Compos 2015; 55(1): 259-67, https://doi.org/10.1016/j.cemconcomp.2014.09.013

[8] Ramezanianpour AA, Mousavi R, Kalhori M, Sobhani J, Najimi M. Micro and macro level properties of natural zeolite contained concretes. Constr Build Mater 2015; 101(1): 347-58, https://doi.org/10.1016/j.conbuildmat.2015.10.101

[9] Markiv T, Sobol K, Franus M, Franus W. Mechanical and durability properties of concretes incorporating natural zeolite. Arch Civ Mech Eng 2016; 16(4): 554-62, https://doi.org/10.1016/j.acme.2016.03.013

[10] Nagrockienė D, Girskas G. Research into the properties of concrete modified with natural zeolite addition. Constr Build Mater 2016; 113: 964-9, https://doi.org/10.1016/j.conbuildmat.2016.03.133

[11] Nagrockienė D, Girskas G, Skripkiūnas G. Properties of concrete modified with mineral additives. Constr Build Mater 2017; 135: 37-42, https://doi.org/10.1016/j.conbuildmat.2016.12.215

[12] Tran YT, Lee J, Kumar P, Kim KH, Lee SS. Natural zeolite and its application in concrete composite production. Compos Part B 2019; 165: 354-64, https://doi.org/10.1016/j.compositesb.2018.12.084

[13] Kumar BN, Rushikesh M, Kumar AA. An experimental study on high strength self-compacting concrete inclusion of zeolite and silica fume as a potential alternative sustainable cementitious materials. Materials Today: Proceedings, 2024; in press, https://doi.org/10.1016/j.matpr.2024.04.063

[14] Zheng X, Wang F, Wu Z, Liu K, Interaction between zeolite and sulfate, and its influences on cement hydration, Cem Concr Compos 2024; 148: 105448m, https://doi.org/10.1016/j.cemconcomp.2024.105448