Stabilized Sand with Zeolite under Impact Load

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ABSTRACT

Cement production has numerous environmental side effects, and it is desirable to reduce the pollutants during cement production. One way of alleviating cement production pollution is by reducing its consumption. Demand for cement can be reduced by introducing alternative materials with the same benefits but are less detrimental to the environment. A natural substitute for cement in infrastructure civil projects is a pozzolan, which is naturally found and is a side product of some industrial processes. One type of pozzolan that has wide availability in Middle Eastern countries is zeolite. Zeolite has been investigated by previous researchers as a replacement for cement for specific types of civil infrastructure development. However, no previous study has investigated zeolite as a substitute for cement for stabilizing sandy soils under impact loading. The feasibility of replacing a percentage of cement with zeolite for stabilizing the sand soil under impact loads is being assessed. Different percentages of cement are replaced with zeolite, and samples are tested under impact loads. Tests indicate that there is an optimum percentage of replacement at which the soil strength under impact loads shows the greatest increase. The optimal replacement percentage is found to be between 30% to 50%. Any replacement below or above that optimal range would hurt the impact strength of the soil samples. The positive effect at optimum replacement percentages can be attributed to the reaction of Calcium Hydroxide and silicate-aluminum structures. Calcium Hydroxide is generated by cement hydration, and silicate-aluminum structures come from the introduction of zeolite into the mix. dealing with any aspect of engineering from fundamental sciences to applications in engineering systems.

KEYWORDS

Sand, Cement, Zeolite, Strength, Impact.

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1. Introduction

Cement production has numerous environmental side effects, and it is desirable to reduce the pollutants during cement production. One way of alleviating cement production pollution is by reducing its consumption. Demand for cement can be reduced by introducing alternative materials with the same benefits but are less detrimental to the environment. A natural substitute for cement in infrastructure civil projects is a pozzolan, which is naturally found and is a side product of some industrial processes. One type of pozzolan that has wide availability in Middle Eastern countries is zeolite. Zeolite has been investigated by previous researchers as a replacement for cement for specific types of civil infrastructure development. The effects of zeolite on the shear strength of cement-stabilized soils have been investigated by Shushpasha et al. (2019) considering different amounts of cement and percentages of its replacement with zeolite [1]. The use of zeolite in combination with crumb rubber for sand stabilization has been studied by Soltani et al. (2014). The best combination was suggested to be 7.5 % crumb rubber in the form of granules and 30 % zeolite as a substitute for cement [2]. In recent years, studies have been conducted on replacing cement with zeolite in soil stabilization [3-6].

This research aims to investigate the effect of replacing cement with zeolite on the impact strength of cement-stabilized sand. This issue has not been investigated in the technical literature. On the other hand, due to the impact nature of dynamic and seismic loads, the resistance to impacts in the form of the final number of impacts that can be tolerated is important. In the present study, an experiment was designed to investigate the effect of zeolite on the impact strength of sand mixed with cement. The samples have different percentages of cement and zeolite.

2. Methodology

The soil used in this study was obtained from the southeastern region of Tehran. The portion of the soil that remained on the No. 200 sieve (fine to medium sand) according to ASTM D 422-63 was used to prepare the samples. Type II Portland cement from Shahrud cement factory was used for the experiments. Clinoptilolite zeolite prepared from Semnan was used. Samples with different percentages of cement of 4, 6, 8 and 10% of the dry weight of the samples were considered. Also, the percentage of cement replacement with zeolite was selected to be 0, 10, 30, 50, 70 and 90 % of the cement weight. To determine the optimum moisture content of the samples and their optimum dry density, standard Proctor compaction tests were performed according to ASTM D698. The curing time of the samples with dimensions of 30 cm x 30 cm x 5 cm was 28 days at a temperature of 23º C.

The impact strength of each sample was considered equal to the number of impacts required to create visible cracks in the samples. The impacts are caused by the free fall of a 250 g weight from a height of 95 cm.

3. Discussion and Results

Figure 1 illustrates the results of impact strength tests for different conditions. The value of impact strength is shown on the vertical axis. The optimal amount of zeolite replacement for all samples is between 30% and 50% of cement. For all samples, replacement of more than 60% to 65% has an adverse effect on the strength. This means that the strength decreases compared to the initial sample of pure cement. For most samples, replacement of 0 to 10% of zeolite does not have a significant effect on the strength.

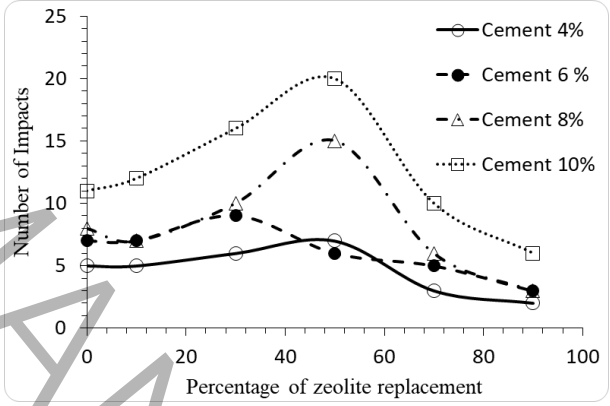

Figure 1. Comparison of impact resistance of samples

The results show that the amount of zeolite in combination with cement has an optimal percentage in all samples. With increasing the amount of zeolite, the strength increases and when the zeolite reaches the optimal percentage, the strength reaches a maximum. If the amount of zeolite exceeds the optimal percentage, the strength decreases. Zeolite contains silicon oxide and aluminum oxide minerals called aluminum silicates. On the other hand, the reaction process of cement and water leads to the production of calcium hydroxide particles. The reaction of aluminum silicate and calcium hydroxide increases the strength. If the amount of zeolite and consequently the amount of aluminum silicate is low, the excess calcium hydroxide does not participate in the reaction and the strength does not increase. On the other hand, if the amount of zeolite is excessive, as a result, the excess amount of aluminum silicate remains in the mixture and reduces the strength.

4. Conclusions

In this study, the effect of zeolite additive on the impact strength of cement-stabilized sand was investigated. According to the results of the experiment designed and constructed in the present study, the optimal percentage of cement replacement with zeolite was suggested for each mixture. The results also show the range of replacement percentages of zeolite that have a negligible or adverse effect on the strength. The optimal replacement amount is between 30% and 50% zeolite. Replacement of more than 65% has an adverse effect on the impact resistance. It is observed that replacement up to 10% does not have a significant effect on the impact strength.

5. References

[1] I. Shooshpasha, M. Abbasi, H. Molaabasi, The Effect of Zeolite on Shear Strength of Babolsar Sand Stabilized with Cement, Journal of Civil and Environmental Engineering, 49.1(94) (2019) 89-96.

[2] M.S. soltani, M. Jiryaei Sharahi, M. Amelsakhi, Effect of Zeolite and tire granules on cement stabilization of the sand, Amirkabir Journal of Civil Engineering, 54(2) (2022) 759-774.

[3] M. Ramezani, S. Soleimani Kutanaei, A. Seyedkazemi, A. Esfandiari Fard, Enhancing the Durability of Cement-Stabilized Clayey Sand with Zeolite and PVA Fibers Under Wet–Dry and Freeze–Thaw Cycles, Transportation Infrastructure Geotechnology, 12(5) (2025) 162.

[4] S. Nasrollahpour, A. Tanhadoust, S. Kaur Brar, H. MolaAbasi, M.L. Nehdi, O. Ataee, Multi-objective optimization of sustainable cement-zeolite improved sand based on life cycle assessment and artificial intelligence, F1000Res, 13 (2024) 257.

[5] L. Cao, P. Cao, Z. Wang, Z. Tan, C. Zhou, G. Zhang, S. Zhang, J. Wang, Performance and environmental impact assessment of a novel zeolite modified cement stabilized calcareous sand material for island eco-construction, Construction and Building Materials, 458 (2025) 139628.

[6] W. Qu, N. Maimt, J. Qu, Effects of zeolite and palm fiber on the weathering resistance and durability characteristic of cement soil, Scientific Reports, 15(1) (2025) 4408.