CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In the process of urbanization, due to the old city reconstruction, engineering construction and other reasons, a large number of construction waste will be generated, such as waste concrete, waste bricks, etc. Among them, China produces 1.55 billion to 2.4 billion tons of construction waste every year (Yuan et al., 2020). However, the traditional construction waste treatment method will not only cause certain harm to the environment, but also waste construction waste to a certain extent. Foamed concrete has the advantages of light weight and controllable compressive strength (Ma et al., 2018; Wang et al., 2020). Since the appearance in 1923, it has been widely used in the fields of foundation treatment (Liu et al., 2020), road widening (Shi et al., 2020), etc. Ordinary foamed concrete is mainly made of cement, foam and water, and its weight is generally 400–1850 kg/m^3 (Raj et al., 2019). Portland cement is an important adhesive in foamed concrete materials. However, relevant research shows that the production of 1 ton of cement will produce about 800 kg of CO_2, and the amount of CO_2 produced by cement accounts for 8% of the total man-made amount (Damtoft et al., 2008). Therefore, it is necessary to prepare construction waste as recycled aggregate and replace it with cement to reduce cement consumption (Oikonomou, 2004).

In order to reveal the influence of added aggregate on the performance of foamed concrete, scholars have carried out a lot of work. Yang et al. (2022) prepared foamed concrete by replacing a certain proportion of cement with recycled concrete powder. It is found that the addition of recycled concrete micro powder has little effect on the dry density of the specimen, but it reduces the compressive strength. Yang et al. (2020) also found that when the replacement rate of recycled brick micro powder was lower than 15%, the 28 day compressive strength of foamed concrete slightly increased, and when the replacement rate was 30%, the associated compressive strength was far lower than the control group. Xiao et al. (2022a) studied the feasibility of using recycled waste concrete fine aggregate to prepare recycled foamed concrete, and analyzed the fluidity, compressive strength, energy absorption and water softening properties of recycled foamed concrete. The above methods can improve the performance of foamed concrete to a certain extent, but there are also some shortcomings. For example, although recycled micro powder and fine aggregate can meet the light characteristics of foamed concrete and better match the characteristics of foamed concrete materials, its cost is high.

1.2 Problem statement

The construction industry is constantly seeking innovative materials that are both cost-effective and environmentally sustainable. Foam concrete, known for its light weight and insulating properties, has been a prominent material for various construction applications. However, its durability under different environmental conditions remains a challenge, particularly when considering the use of alternative additives to enhance its properties. This investigation seeks to explore the durability of hybrid foam concrete when enhanced with palm kernel oil surfactant, a byproduct of the palm oil industry. The influence of various curing conditions on the durability of this hybrid foam concrete will be evaluated, as the potential for improving the material's performance under different exposure environments could make it a viable option for more sustainable and robust construction solutions.

1.3 Justification of Study

The growing demand for sustainable construction materials, coupled with the need to reduce environmental impact, has driven research into more eco-friendly alternatives. Palm kernel oil (PKO) is an abundant and renewable resource that could be used as a surfactant to enhance the properties of foam concrete. By incorporating PKO as a surfactant, there is potential to improve the workability, durability, and strength of foam concrete. However, the specific effects of PKO on foam concrete's long-term performance under varying curing conditions have not been extensively studied. This study aims to fill this gap by evaluating how different curing conditions—such as air, water, and steam curing—impact the durability of foam concrete with palm kernel oil surfactant. The findings could provide valuable insights into the feasibility of using palm kernel oil-based surfactants in sustainable construction practices, offering a more environmentally friendly and cost-effective alternative to conventional concrete additives.

1.4 Aim of the Study

Investigation of the durability of hybrid foam concrete with palm kernel oil surfactant under different curing conditions.

1.5 Objectives of the Study

The specific objectives of this research are to:

i. Determine the optimal concentration of palm kernel oil surfactant that enhances the durability of foam concrete.

ii. Evaluate the impact of palm kernel oil surfactant on the compressive strength and water absorption of foam concrete under various curing methods (water curing, air curing, and steam curing).

iii. Assess freeze-thaw resistance of foam concrete with palm kernel oil surfactant when exposed to different curing techniques.

iv. Compare the performance of foam concrete with and without palm kernel oil surfactant under identical curing conditions to understand the effects of the surfactant on long-term durability.

1.6 scope of Study

This study will focus on the investigation of the durability of hybrid foam concrete enhanced with palm kernel oil surfactant, subjected to different curing conditions. The scope includes:

1. **Preparation of Foam Concrete Samples**: Foam concrete samples will be mixed with palm kernel oil surfactant at varying concentrations to determine the optimal formulation for durability improvement.
2. **Curing Conditions**: The study will examine three primary curing conditions—air curing, water curing, and steam curing—each of which is commonly used in construction to assess their effects on the performance of the hybrid foam concrete.
3. **Durability Testing**: The durability of the foam concrete samples will be tested under conditions simulating real-world environmental stress, such as exposure to moisture, temperature fluctuations, and mechanical load. Specific tests will include compressive strength, water absorption, shrinkage, and freeze-thaw resistance.
4. **Comparison with Traditional Foam Concrete**: The performance of the hybrid foam concrete will be compared to that of conventional foam concrete without surfactant and foam concrete with typical synthetic surfactants.
5. **Data Analysis**: The results will be analyzed to assess the effect of PKO surfactant and different curing conditions on the material's durability, comparing the performance of each formulation and curing method.

References

- *Neville, A. M., & Brooks, J. J. (2010). Concrete Technology. Pearson Education.*
- *Sadeghian, P., & Ramezanianpour, A. A. (2015). "Effect of surfactants on the stability of foam concrete." Construction and Building Materials, 76, 278-286.*
- *Zhang, M., & Islam, R. (2013). "Durability performance of lightweight foam concrete in aggressive environments." Materials and Structures, 46(2), 271-283.*
- *Gani, S. S., & Sajjad, M. (2019). "Palm kernel oil-based surfactants for use in construction materials: A sustainable approach." Journal of Cleaner Production, 214, 463-470.*
- *John, V. M., & Kumar, A. (2020). "Effects of curing methods on the durability of foam concrete." Cement & Concrete Composites, 108, 103480.*
- *Zhang, Y., & Cai, Y. (2020). "Hydrogen peroxide as a foaming agent for lightweight concrete." Journal of Building Engineering, 31.*
- *Gani, S. S., & Sajjad, M. (2019). "Palm kernel oil-based surfactants for use in construction materials: A sustainable approach." Journal of Cleaner Production, 214, 463-470.*
- □ *John, V. M., & Kumar, A. (2020). "Effects of curing methods on the durability of foam concrete." Cement & Concrete Composites, 108, 103480.*
- □ *Neville, A. M., & Brooks, J. J. (2010). Concrete Technology. Pearson Education.*
- □ *Sadeghian, P., & Ramezanianpour, A. A. (2015). "Effect of surfactants on the stability of foam concrete." Construction and Building Materials, 76, 278-286.*
- □ *Zhang, M., & Islam, R. (2013). "Durability performance of lightweight foam concrete in aggressive environments." Materials and Structures, 46(2), 271-283.*
- □ *Zhang, Y., & Cai, Y. (2020). "Hydrogen peroxide as a foaming agent for lightweight concrete." Journal of Building Engineering, 31.*
- □ *hia, K. W., et al. (2018). Properties of hybrid foam concrete: A comprehensive review. Journal of Building Engineering, 18, 145-159.*
- □ *Khatri, S. R., & Patel, M. (2018). Effect of surfactants on the properties of foam concrete. International Journal of Engineering and Technology, 7(2), 65-73.*
- □ *Liu, Z., et al. (2018). Properties and applications of foam concrete: A review. Construction and Building Materials, 163, 385-397.*
- □ *Mehta, P. K., & Monteiro, P. J. (2006). Concrete: Microstructure, Properties, and Materials. McGraw-Hill.*
- □ *Mindess, S., Young, J. F., & Darwin, D. (2003). Concrete. Pearson Education.*
- □ *Neville, A. M. (2011). Properties of Concrete. Longman.*
- □ *Weng, L. M., et al. (2015). Effect of palm kernel oil surfactant on the properties of foam concrete. Journal of Sustainable Construction Materials and Technologies, 10, 119-125.*

- *Voon, C. H., et al. (2017). Use of palm oil-based surfactants in the development of green concrete. Environmental Engineering Science, 34(8), 577-585.*

- *Imran, Y., Farzadnia, N., and Ali, A. (2015). Properties and applications of foamed concrete; a review. Constr. Build. Mater. 101, 990–1005. doi:10.1016/j.conbuildmat.2015.10.112*

- *Beshr, h., Almusallam, A., and Maslehuddin, M. (2003). Effect of coarse aggregate quality on the mechanical properties of high strength concrete. Constr. Build. Mater. 17 (2), 97–103. doi:10.1016/s0950-0618(02)00097-1*

- *Damtoft, J. S., Lukasik, J., Herfort, D., Sorrentino, D., and Gartner, E. (2008). Sustainable development and climate change initiatives. Cement.Concr. Res. 38 (2), 115–127. doi:10.1016/j.cemconres.2007.09.008*

- *Favaretto, P., Hidalgo, G., Sampaio, C., Silva, R., and Lermen, R. (2017). Characterization and use of construction and demolition waste from south of Brazil in the production of foamed concrete blocks. Appl. Sci. 7 (10), 1090. doi:10.3390/app7101090*

- *Ibrahim, N., Ismail, K., Amat, R., Rahim, N., and Nazmi, N. (2020). Potential use of foam in the production of lightweight aggregate (LWA) and its performance in foamed concrete. IOP E. E. S. 476 (1), 012037. doi:10.1088/1755-1315/476/1/012037*

- *Kang, Y., Jia, Y., and Luo, Y. (2018). Fracture morphology and mechanism of concrete cube test blocks subjected to compression failure. J. Xi'an Univ. Archit. Technol. 50 (02), 202–208.*
- *Krishna, A., Siempu, R., and Kumar, G. (2021). Study on the fresh and hardenedproperties of foam concrete incorporating fly ash. Mater. Today Proc. 46, 8639–8644. doi:10.1016/j.matpr.2021.03.599*
- *Liu, K., Yue, F., S, Q., Zhou, C., Xiong, Z., and He, Y. (2020). Assessment of the use of fiberglass-reinforced foam concrete in high-speed railway bridge approach involving foundation cost comparison. Adv. Struct. Eng. 23 (2), 388–396. doi:10.1177/1369433219867622*
- *Liu, Z., Zhao, K., Hu, C., and Tang, Y. (2016). Effect of water-cement ratio on pore structure and strength of foam concrete. Adv. Mater. Sci. Eng. 2016, 1–9. doi:10.1155/2016/9520294*
- *Ma, C., and Chen, B. (2015). Properties of a foamed concrete with soil as filler. Constr. Build. Mater. 76, 61–69. doi:10.1016/j.conbuildmat.2014.11.066*
- *Ma, S., Chen, W., and Zhao, W. (2018). Mechanical properties and associated seismic isolation effects of foamed concrete layer in rock tunnel. J. Rock. Mech.Geotech. Eng. 11 (1), 159–171. doi:10.1016/j.jrmge.2018.06.006*
- *Ministry of Housing and Urban Rural Development (2012). CJJ/T177-2012, Technical specification for foamed mixture lightweight soil filling engineering. Beijing, China: Ministry of Housing and Urban Rural Development.*

- *Ministry of Housing and Urban Rural Development (2011). JG/T 266-2011, Foamed concrete. Beijing, China: Ministry of Housing and Urban Rural Development.*
- *Nambiar, E., and Ramamurthy, K. (2007). Sorption characteristics of foam concrete. Cement.Concrete. Res. 37 (9), 1341–1347. doi:10.1016/j.cemconres.2007.05.010*
- *Oikonomou, N. (2004). Recycled concrete aggregates. Cement.Concrete. Comp. 27 (2), 315–318. doi:10.1016/j.cemconcomp.2004.02.020*
- *Oren, O., Gholampour, G., Gencel, O., and Ozbakkaloglu, T. (2020). Physical and mechanical properties of foam concretes containing granulated blast furnace slag as fine aggregate. Constr. Build. Mater. 238, 117774. doi:10.1016/j.conbuildmat.2019.117774*
- *Osman, G., Turhan, B., Zeynep, B., and Togay, O. (2022). A detailed review on foam concrete composites: Ingredients, properties, and microstructure. Appl. Sci. 12 (11), 5752. doi:10.3390/app12115752*
- *Pasupathy, K., Ramakrishnan, S., and Sanjayan, J. (2021). Influence of recycled concrete aggregate on the foam stability of aerated geopolymer concrete. Constr. Build. Mater. 271, 121850. doi:10.1016/j.conbuildmat.2020.121850*
- *Raj, A., Sathyan, D., and Mini, K. (2019). Physical and functional characteristics of foam concrete: A review. Constr. Build. Mater. 221, 787–799. doi:10.1016/j.conbuildmat.2019.06.052*
- *Shen, W., Dong, R., Li, J., Zhou, M., Ma, W., and Zha, J. (2010). Experimental investigation on aggregate interlocking concrete prepared with scattering–filling coarse aggregate process. Constr. Build. Mater. 24 (11), 2312–2316. doi:10.1016/j.conbuildmat.2010.04.023*
- *Shen, W., Zhang, C., Li, X., Shi, H., Wang, G., and Tian, X. (2014). Low carbon concrete prepared with scattering-filling coarse aggregate process. Int. J.Concr.Struct. M. 8 (4), 309–313. doi:10.1007/s40069-014-0080-5*
- *Shi, X., Huang, J., and Su, Q. (2020). Experimental and numerical analyses of lightweight foamed concrete as filler for widening embankment. Constr. Build. Mater. 250, 118897. doi:10.1016/j.conbuildmat.2020.118897*
- *Stock, A., Hannantt, D., and Williams, R. (1979). The effect of aggregate concentration upon the strength and modulus of elasticity of concrete. Mag. Concr. Res. 31 (109), 225–234. doi:10.1680/macr.1979.31.109.225*
- *Ulsen, C., Tseng, E., Angulo, S., Landmann, M., Contessotto, R., Balbo, J., et al. (2019). Concrete aggregates properties crushed by jaw and impact secondary crushing. J. Mater. Res. Technol. 8 (1), 494–502. doi:10.1016/j.jmrt.2018.04.008*
- *Verian, K., Ashraf, W., and Cao, Y. (2018). Properties of recycled concrete aggregate and their influence in new concrete production. Resour. Conserv. Recy. 133, 30–49. doi:10.1016/j.resconrec.2018.02.005*
- *Wang, X., Huang, J., Dai, S., Ma, B., and Jiang, Q. (2020). Investigation of silica fume as foam cell stabilizer for foamed concrete. Constr. Build. Mater. 237 (C), 117514. doi:10.1016/j.conbuildmat.2019.117514*
- *Wang, X., Liu, L., Jia, K., and Zhou, H. (2021). Mechanical properties and energy absorption characteristics of ceramsite foam concrete. J. Build. Mater. 24 (01), 207–215.*

- *Wang, X., Liu, L., Zhou, H., Song, T., Qiao, Q., and Zhang, H. (2021). Improving the compressive performance of foam concrete with ceramsite: Experimental and meso-scale numerical investigation. Mater. Des. 208, 109938. doi:10.1016/j.matdes.2021.109938*
- *Wu, L., Yao, J., Gao, S., Zhu, X., Zhou, B., and Xu, X. (2015). Research on factors affecting physical and mechanical properties of pre -placed concrete slabs with recycled brick aggregate manufactured by grouting. J. Water Resour. Archit. Eng. 13 (06), 214–220.*
- *Xiao, J., Hao, L., Cao, W., and Ye, T. (2022). Influence of recycled powder derived from waste concrete on mechanical and thermal properties of foam concrete. J. Build.Eng. 61, 105203. doi:10.1016/j.jobe.2022.105*
- *Xiao, J., Zhang, H., Zou, S., Duan, Z., and Ma, Y. (2022). Developing recycled foamed concrete for engineered material arresting system. J. Build. Eng. 53, 104555. doi:10.1016/j.jobe.2022.104555*