

Article

Preparation of Ceramsite Using Dehydrated Silt Soil and Its Performance on Compressive Strength of Ceramsite Concrete Block

Jiawei Zang ¹, Chonggen Pan ^{2,*} , Yu Hu ¹ and Shiyang Qu ¹

¹ Department of Structural Engineering, College of Civil Engineering and Architecture, Zhejiang University, No. 866 Yuhangtang Road, Xihu, Hangzhou 311400, China; 22012235@zju.edu.cn (J.Z.); 22112227@zju.edu.cn (Y.H.)

² Department of Civil Engineering, School of Civil Engineering & Architecture, NingboTech University, No. 1 Qianhu South Road, Yinzhou, Ningbo 315100, China

* Correspondence: panchonggen@zju.edu.cn

Abstract: Using dehydrated silt soil as a raw material to produce ceramsite for ceramsite concrete blocks is a promising approach from both environmental and economic aspects. In this paper, flocculant polyacrylamide (PAM) was investigated to dehydrate the silt, and the optimal dosage of PAM was found to be 0.8 mol/L. The dehydrated silt was then fired to obtain ceramsite, which was subsequently used to prepare ceramsite autoclaved concrete blocks (CACB). The compressive strength of the blocks was tested and compared with that of ordinary autoclaved concrete blocks (ACB) and Nano-CaCO₃ autoclaved concrete blocks (NACB). The results showed that the addition of ceramsite or Nano-CaCO₃ can improve the compressive strength, with an increase of 44.4% and 55.6% at 7 d, respectively, compared with the autoclaved concrete block.

Keywords: flocculant; silt dehydration; ceramsite; autoclaved concrete blocks



Citation: Zang, J.; Pan, C.; Hu, Y.; Qu, S. Preparation of Ceramsite Using Dehydrated Silt Soil and Its Performance on Compressive Strength of Ceramsite Concrete Block. *Sustainability* **2023**, *15*, 9134. <https://doi.org/10.3390/su15119134>

Academic Editor:
José Ignacio Alvarez

Received: 16 March 2023
Revised: 8 April 2023
Accepted: 23 April 2023
Published: 5 June 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

River silt is a kind of porous clay deposited under natural conditions, such as hydraulic power, formed by physical and chemical action and has a water content of 30~90% [1]. As one of the largest rivers in the world, Changjiang River has a super-large-scale silt zone with a length of 1000 km, and the total mass of flowing silt in this area is about 800 million tons [2]. The massive deposition of this silt would cause the collapse of the river ecosystem and eventually lead to serious pollution, such as water blooms, on the water environment. Although China has invested substantial funding to improve water environments and develop special river regulations, statistics have shown that billions of cubic meters of river silt have been produced by dredging [3], which needs to be treated urgently.

Silt is characterized by its high moisture content and complex distribution of clay particles. In the long-term practice of silt treatment technology abroad, methods such as landfill, dehydration, sintering, and solidification are commonly used. However, due to the large amount of silt produced, the practice of solidification followed by landfill is unsustainable. Therefore, finding sustainable ways to utilize solidified silt is crucial for its disposal. One promising method is to use solidified silt to produce ceramsite, a raw material for concrete blocks with multiple advantages of being lightweight and low strength, and providing other properties such as fire prevention, heat preservation and sound insulation. This method is both environmentally friendly and cost-effective [4]. This approach not only turns silt into a valuable resource but also ensures economic and sustainable waste disposal, making it an effective means for solid waste management.

1.1. Silt Dewatering Technology

Traditionally, sludge dewatering involves methods such as filter press dewatering, extrusion dewatering, and geotechnical tube belt dewatering, and they all have a low treatment efficiency. To meet strict dehydration requirements during construction, more efficient technical means are required. The use of preliminary chemical conditioning, combined with corresponding technologies, can achieve deep and rapid dehydration and a low cost. Although sludge dewatering technology is widely used, there is still a dewatering threshold. The core of this technology is to reduce the specific filtration resistance of sludge, which leads to improved dewatering performance. For example, filter press dehydration typically starts with a specific filtration resistance of $800\text{--}1500 \times 10^{10}$ m/kg, which results in poor dehydration performance. However, after the best flocculation treatment, the specific filtration resistance drops to between 100 and 400×10^{10} m/kg, resulting in sludge that meets dehydration requirements.

1.1.1. Flocculants

Flocculants have been widely used in fields, including river silt, municipal silt, and industrial wastewater treatment, aiming to improve the dewatering performance of silt by aggregating and merging solid waste materials with a high water content through adsorption and neutralization, particle bridging, and roll-swept net capture. Flocculants can be divided into inorganic, organic, composite, and microbial, and their performance characteristics are summarized in Table 1.

Table 1. Performance characteristics of various flocculants.

Category	Examples	Advantages and Disadvantages
Inorganic flocculants	aluminum sulfate, iron sulfate, poly-aluminum chloride [5]	Low cost and simple process, but large dosage and poor effect.
Organic flocculants	chitosan, chitin, polyacrylamide, sodium polyacrylate, polyamine [6]	Excellent performance, low dosage, and stable performance, but the monomer has little toxicity.
Composite flocculants	polymeric aluminum ferric chloride, polymeric aluminum ferric sulfate, starch copolymer [7]	High efficiency, but high cost and complex synthesis.
Microbial flocculants	polysaccharides, proteins [8]	Ability of self-decomposition and excellent performance, but there is little related research and the preparation is difficult.

1.1.2. Curing Agents

The building materials' industry utilizes various inorganic cementing materials as curing agents, including cement, lime, gypsum, and slag, to create solidification materials. These materials contain primarily silicon dioxide, calcium oxide, and some iron and aluminum oxides. Even some solid wastes with gelling properties, such as phosphogypsum, fly ash, and various slag, can serve as potential inorganic curing agents. Organic compounds such as sulfonated oil, potassium polyacrylate, and super absorbent resins have also demonstrated curing effects. These organic curing agents, unlike inorganic ones, do not undergo any chemical changes during curing. Curing agents can form strong binding forces between silt particles through their micro-long-chain coating, macro-structure adsorption, and cohesion. In this study, cement was chosen as the silt solidification agent.

1.2. Autoclaved Aerated Concrete Blocks

The autoclaved aerated concrete block is a popular and eco-friendly building material worldwide due to its lightweight and cost-effective nature. However, its thermal insulation

performance has been affected by cracking, leakage, and reduced thermal insulation recently, hindering its wider application [9,10]. Therefore, it is essential to develop an external self-thermal insulation wall material with excellent volume stability, high specific strength, and good thermal insulation performance.

The concept of autoclaved aerated concrete was first introduced by Swedish architect Johan Axel Eriksson and has been commercially produced for over 90 years. Research on the improvement in its performance has been completed by many scholars [10–14]. Various studies have shown that hydration products, porosity, and pore uniformity have a significant impact on the compressive strength, water absorption, and shrinkage of autoclaved aerated concrete blocks [11–15]. To ensure quality, the process flow was optimized based on these findings.

In China, autoclaved aerated concrete was introduced in the mid-20th century, and researchers have carried out various studies to improve its quality. Studies conducted by Sun Baozhen, Ma Yu, and others using the control variable method showed that the compressive strength of autoclaved aerated concrete blocks increases with the increase in hydration products and the decrease in water content [15–18]. However, the mass loss and strength loss of the block under the freeze–thaw cycle increase with the number of freeze–thaw cycles [16–19]. Tests and simulations by Peng Junzhi, Cui Jingjie, and others have revealed that the lower the moisture content of autoclaved aerated concrete, the higher the porosity, and the smaller the thermal conductivity of the block [20–23].

Ceramsite Autoclaved Aerated Concrete Block

The ceramsite autoclaved aerated concrete block is a porous silicate block that is made by using ceramsite as an aggregate, along with fly ash, cement, and lime as cementitious materials. This mixture is then combined with appropriate additives and aluminum powder as an aerating agent. Once water is added to the mixture, it is poured into a mold, where it undergoes aeration expansion, pre-curing, cutting, and finally, curing by high-pressure steam [24–27]. This block is a unique combination of ceramsite concrete and aerated concrete, which has many advantages over traditional building materials.

One of the most significant advantages of the ceramsite aerated concrete block is its lightweight density, which ranges from 450 to 750 kg/m³. This is only one-third of the weight of red bricks and one-fourth of the weight of concrete, which can significantly reduce the dead weight of the building. This block has excellent thermal insulation capacity, with a thermal conductivity of 0.11 to 0.18 W/m² K, which is three to four times that of clay brick and four to eight times that of ordinary concrete. In some areas, a 240 mm thick ceramsite aerated block wall can meet the requirement of 50% energy saving [26].

The ceramsite aerated concrete block has also been found to have high compressive strength, reaching grade B07 with a compressive strength of more than 7.5 MPa [27]. This high-strength utilization rate makes it a suitable material for building walls and other load-bearing structures. The numerous air holes in the block provide excellent sound insulation and sound absorption, making it an ideal choice for building walls with special requirements for sound insulation.

Another significant advantage of the ceramsite aerated concrete block is its environmentally friendly production process, which is zero waste gas, waste water, or waste residue. This production process results in energy savings, land savings, and material savings/waste utilization.

The development and research of lightweight aggregates began in foreign countries as early as the 19th century, with continuous research leading to the development of lightweight ceramsite [28]. Ceramsite concrete has been used mainly for non-load-bearing structures such as large wallboards and blocks in countries such as Denmark and Austria. Japan has actively developed high-performance aggregates since World War II, and China started research on ceramsite lightweight aggregates in the 1950s, with the development of high-strength ceramsite concrete beginning in the 1970s. The Tianjin Institute of Building Science has successfully prepared LC40 high-strength fly ash ceramsite concrete

in the laboratory, making a new breakthrough in the research and development of new wall materials.

1.3. Research Objectives

This paper aims to study and verify the feasibility of the sustainable industrial method of recycling silt into building materials through the process of “dewatering silt-firing ceramsite-preparing concrete blocks”. The research contents include the influence of flocculant dosage and dehydration time on the dehydration effect, and the strength study of ceramsite autoclaved aerated concrete block (compared with autoclaved aerated concrete block with nano-calcium carbonate).

2. Preparation of Raw Materials and Experimental Design

2.1. Raw Materials

(1) Muddy soil

The soil sample used in this experiment comes from the muddy muck of engineering construction in a coastal area. The basic property index is showed in Table 2.

Table 2. Basic property index of experimental soil.

Water Content (%)	Density (g·cm ⁻³)	Proportion (%)	Liquid Limit	Plastic Limit
60	1.68	2.57	55	28

(2) Flocculant polyacrylamide (PAM)

PAM used in this paper was produced by Da Qian Huan Bao Technology Co., Ltd., and the technical index is shown in Table 3.

Table 3. Technical index.

Items	Index
Particle size (mm)	≤1
Solid content (%)	≥89
Dissolution rate (h)	≤2
Insoluble substance (%)	≤0.2
Degree of hydrolysis (%)	20~30
pH	5~7

(3) Cement

P·O 42.5 ordinary Portland cement produced by Zhejiang Qianchao Holding Co., Ltd. (Hangzhou, China) was used, of which the specific surface area is about 315 m²/kg and the specific gravity is 3.14. The technical properties of conch 42.5 ordinary Portland cement are shown in Table 4.

Table 4. Performance of conch 42.5 ordinary Portland cement.

Compressive Strength (MPa)		Flexural Strength (MPa)		Requirement of Normal Consistency (%)
7 d	28 d	7 d	28 d	
28.3	48.7	5.7	8.1	28.2

(4) Class II fly ash was from Beilun Power Plant, of which the technical indicators meet the requirements of Fly Ash for Cement and Concrete (GB/T 1596), as shown in Table 5.

Table 5. Properties of fly ash compared with Specifications for Class II fly ash.

Fly Ash Category	Loss on Ignition (%)	Water Content (%)	Water Demand Ratio (%)	Fineness (%)	Activity Index (%)
Fly ash from Beilun Power Plant	1.6	0.30	96	22.3	96.2
Specification for Class II fly ash	≤8.0	≤1.0	≤105	≤25.0	≥70

(5) Sand

ISO sand (GB/T17671) with a specific gravity of 2.67 and a fineness modulus of 2.68 was used.

(6) Nano-CaCO₃

The Nano-CaCO₃ used in this paper was produced by Shanghai Yuanjiang Chemical Co., Ltd., Shanghai, China. Its fineness modulus is a 5000 mesh.

2.2. Preparation of Test Pieces

2.2.1. Firing Ceramsite

To produce high-quality ceramsite, several crucial steps must be followed. Initially, the bottom mud was dried, crushed, and screened before being ground, and then the powder was mixed with an additive for uniformity. Water was added to the mixture to form pellets, with a moisture range of 10% to 30% to ensure superior results. The pellets must have a smooth spherical surface without any cracks or other visible defects. After molding, the pellets were placed in a room free from direct sunlight and wind to dry naturally for 24 h. The pellets were then transferred to an electric furnace and heated gradually to remove any remaining moisture. In addition, in the preheating stage, the gas generated by the internal reaction of the pellets gradually softens the pellets, so as to prepare for the liquid phase generated by the melting of the pellets and a large number of gas-producing reactions during the expansion process. Therefore, it is essential to control the preheating temperature and time within a reasonable range to achieve optimal gas production for the best expansion effect. In this paper, the pellets were preheated at 450 °C for 20 min, and then fired at 900 °C for 15 min. Once sintering was complete, the pellets were cooled inside the furnace. During the cooling process, the pellet's surface becomes denser and harder, forming many closed pores on the inside.

2.2.2. Concrete Blocks

The autoclaved aerated concrete blocks (70.7 mm × 70.7 mm × 70.7 mm) with ceramsite and different amounts of Nano-CaCO₃ (0%, 1%, 2% and 3%) were manufactured, and the mix ratio is shown in Table 6. Six parallel test blocks were made repeatedly for each group of tests. The compressive strength of the block at different curing periods was measured. The specific experimental steps are as follows:

- (1) Weigh fly ash, sand, and gypsum, add water and mix for 60 s;
- (2) Then, add the weighed quicklime and cement, and mix for 120 s;
- (3) Weigh an appropriate amount of aluminum powder, add and stir for 60 s.

Table 6. Properties of fly ash.

Number	Cement	Lime	Fly Ash (Sand)	Gypsum	Aluminum Powder	Water-Cement Ratio	Ceramsite	Nano-CaCO ₃
1	10%	21%	65%	4%	0.9%	60%	0%	0%
2	10%	21%	65%	4%	0.9%	60%	20%	0%
3	10%	21%	65%	4%	0.9%	60%	0%	1%
4	10%	21%	65%	4%	0.9%	60%	0%	2%
5	10%	21%	65%	4%	0.9%	60%	0%	3%

2.3. Effect of Flocculation Time on Dewatering Capacity

To ensure accurate and consistent test results, these steps were followed before conducting the flocculation and dehydration test of waste mud. An amount of 1.0 g of polyacrylamide was precisely weighed using an electric balance and set aside in a test tube. This was followed by mixing the waste mud of drilling clay in a plastic bucket thoroughly using a small, hand-held electric mixer, to ensure its uniform distribution. The ground mixture was diluted with distilled water, with a water and soil ratio of 2:1, to make the solution, 500 mL of which was collected into a 500 mL beaker. The pre-weighed polyacrylamide was added to the waste mud solution and stirred for 1 min with a glass rod to ensure complete mixing. The mixture was allowed to stand for a certain period to observe the flocculation process, and then the dewater amount was measured with a measuring cylinder. Finally, the procedure was repeated eight times, as described in Table 7.

Table 7. Dehydration and flocculation time grouping.

Group	A	B	C	D	E	F	G	H
Flocculation time (min)	5	10	20	30	60	90	120	150

2.4. Effect of Dosage of Flocculant on Dewatering Capacity

To maintain consistency in each test, the following steps were taken before conducting the flocculation and dehydration test of waste mud. The required mass of polyacrylamide was precisely weighed using an electronic balance and was set in a test tube. The waste mud of drilling clay was mixed thoroughly in a plastic bucket to ensure uniform distribution, using a small, hand-held electric mixer, which was immediately transferred to a 500 mL beaker with a soil and water weight ratio of 1:2. The pre-weighed reagent was added to the waste mud sample and mixed for 1 min with a glass rod to ensure the flocculant was evenly dispersed in the waste mud. The mixture was allowed to stand for 90 min for flocculation, before measuring the amount of water removal using a measuring cylinder. The procedure was repeated eight times, as outlined in Table 8.

Table 8. Dewatering capacity and flocculant consumption grouping table.

Group	A	B	C	D	E	F	G	H
polyacrylamide (g)	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6

2.5. Compressive Strength Test of Block

The purpose of this test was to determine the compressive and flexural strength of the test piece after 1 day, 3 days, and 7 days. The testing method conformed to the Standard for Test Methods of Mechanical Properties of Ordinary Concrete (GB/T50081-2002) [19]. The compressive strength test specimen measured 70.7mm × 70.7mm × 70.7mm and was tested using the SYE-300 pressure testing machine from Zhejiang Zhongke Instrument Co., Ltd. (Hangzhou, China). The test pieces had a strength grade of 1, and a maximum load of 300 kN. Three test pieces were prepared for each group.

During the compression test, the load was applied continuously at a speed of 0.6~0.8 MPa per second. When the test piece started to deform sharply and was close to failure, the accelerator of the testing machine was adjusted to maintain a steady load until it broke, and the failure load was recorded.

The compressive strength of the test piece can be calculated using the following formula:

$$f_c = F/A \quad (1)$$

where:

f_c —compressive strength of test piece (MPa);

F —specimen failure load (N);

A —bearing area of test piece (mm²), 4998.59 mm² for this study.

The measured compressive strength is multiplied by the dimension conversion factor of 0.95.

2.6. Scanning Electron Microscope

After the strength test, the surface morphology of the cement hydrated samples was analyzed by a scanning electron microscope (SEM), the Zeiss EVO-18, manufactured in Germany. Those samples were blank sample blocks, which were immersed in anhydrous ethanol for 24 h to prevent further hydration.

3. Results and Discussion

3.1. Relationship between Flocculation Effect and Flocculation Time

As polyacrylamide is added and stirred, the solution gradually becomes clear, and large amounts of flocculent substances begin to precipitate. The stirring process was found to accelerate the precipitation process. In Figure 1b, after stirring, the beaker shows clear layering with a top layer of clear liquid and a bottom layer of silt substances, while the surface of the beaker shows a few crystals. The beaker is left to settle, and with time, the upper layer of supernatant increases while the height of the soil layer at the bottom rises. The number of crystals on the surface remains relatively constant. The state before and after flocculation is shown in Figure 1.

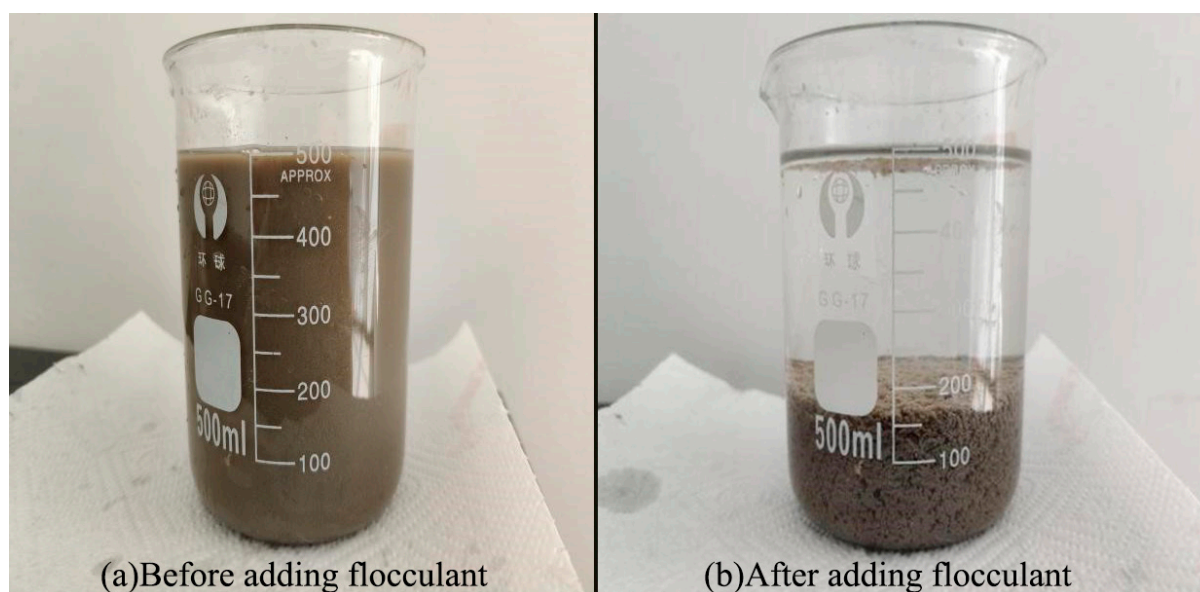


Figure 1. Comparison before and after adding flocculant for 90 min.

Figure 2 shows the dewatering capacity with the flocculation time. After five minutes, a significant amount of water is measured. Over time, the flocculated soil particles begin to settle at the bottom of the beaker under the influence of gravity, resulting in an increasing

amount of water removal. After 90 min, the change in the water removal rate becomes less noticeable, indicating the end of the flocculation process. Undissolved white crystals of polyacrylamide are floating on the surface. The low solubility of polyacrylamide in water is due to factors such as temperature and atmospheric pressure during dissolution. Polyacrylamide gradually dissolves in water over time until it reaches the solubility limit; the 1 g/500 mL ratio results in insufficient polyacrylamide dissolution.

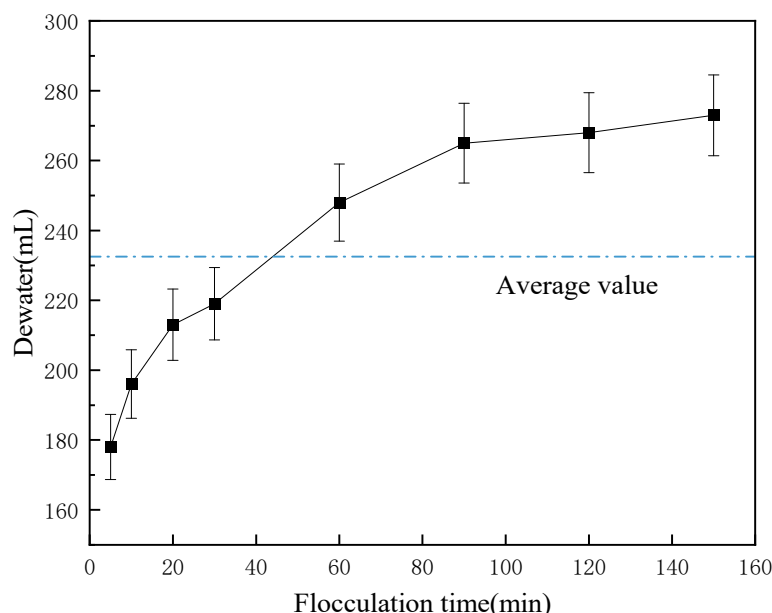


Figure 2. Effect of flocculation time on dewatering capacity.

3.2. Relationship between Flocculation Effect and Dosage of Flocculant

After the addition of polyacrylamide and initiation of stirring, the solution's upper layer gradually becomes clear while a significant amount of flocculent particles precipitate. The speed of the supernatant precipitation increases with an increasing amount of polyacrylamide, and the phenomenon becomes more pronounced after stirring. In cases where the flocculant amount is low (below 0.8 g/mL), the lower part of the soil appears as clumps of flocculent particles with small sizes, which can be easily felt due to their apparent viscosity. However, when a large amount of flocculant is added (above 1 g/mL), the dewatering effect is less effective. After the removal of the supernatant from the upper layer, the water from the lower layer combines with the lower part of the soil to form a binding material, causing the particles to pile up. When the lower part is poured out, it may result in the phenomenon of wire drawing. The effect of adding different doses of flocculant is shown in Figure 3.

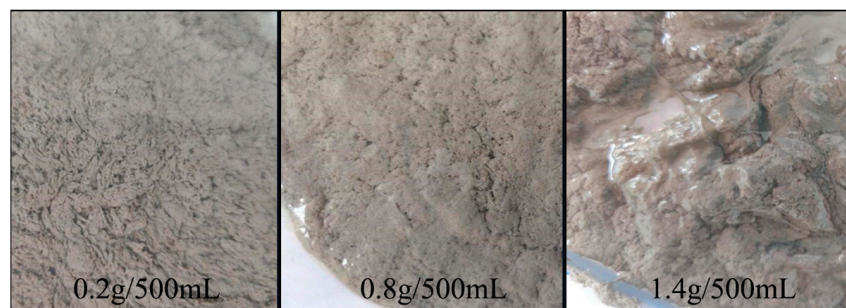


Figure 3. Flocculation effect of different flocculant dosages.

As shown in Figure 4, the effect of flocculant dosage on dehydration is evident in the soil treatment process. When the dosage is less than 1.2 g/L, dehydration increases

as the dosage of flocculant increases. However, when the dosage exceeds 1.2 g/L, the dehydration quantity decreases as the dosage increases. This can be attributed to the fact that increasing the flocculant dosage leads to the formation of a glue-like substance that cannot be separated from the lower part of the soil, resulting in an increase in viscosity. This also makes it more challenging to mix the soil with rice ears to prepare ceramsite, which in turn requires more polyacrylamide and increases the cost. Nevertheless, a certain amount of viscosity is required for the basic soil to prepare ceramsite. Therefore, the optimal dosage of flocculant for soil treatment is 0.8 g/L.

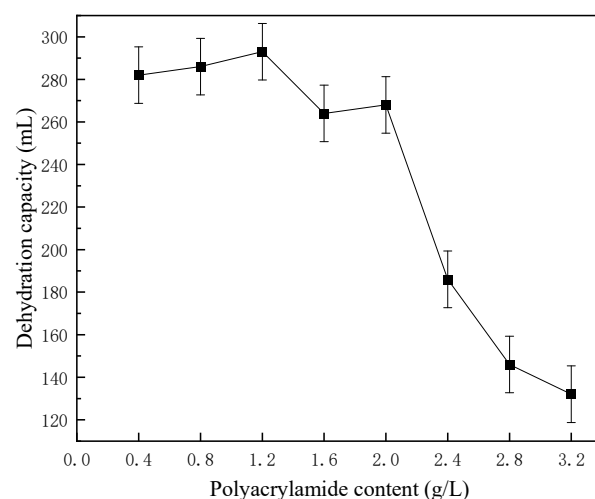


Figure 4. Effect of dosage of flocculant on dewatering capacity.

3.3. Compressive Strength Test of Concrete Block

Figure 5 shows that the compressive strength of the Nano- CaCO_3 -added test block is 44.4% higher than that of the base test block and reaches the highest at 1% Nano- CaCO_3 . The optimal amount of Nano- CaCO_3 added does not indicate that more Nano- CaCO_3 added results in a greater compressive strength. When the amount of Nano- CaCO_3 added is 1%, the compressive strength of the autoclaved aerated concrete test block is the highest. Compared with the blank mortar, the compressive strength of the test block with 20% ceramsite is improved by 49.8%, similar to the research results of Wang [29]. This result is even greater than that of the test block with 1% nano-calcium carbonate, which means that ceramsite can significantly improve the mechanical properties of mortar and can obtain a certain compressive strength at a lower cost.

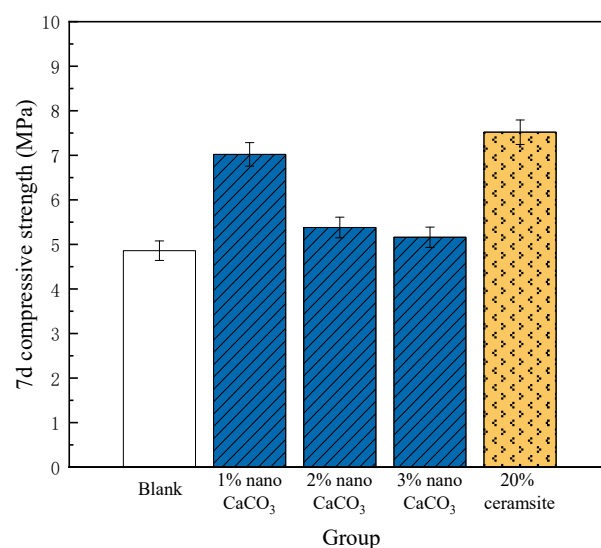


Figure 5. Effect of Nano- CaCO_3 content on compressive strength.

3.4. SEM Diagram of Autoclaved Aerated Concrete Test Block

Each group of test blocks after 7 d curing were broken and sampled, and the SEM images were obtained by electron microscope observation. The letters a, b, and c represent the SEM images at the magnification of 2500, 5000, and 10,000, respectively.

Both results from the compressive test and the SEM (Figures 6–8) infer that Nano- CaCO_3 can promote the crystallization of hydrated products and ultimately enhance the macroscopic strength of the resulting product. The micro-aggregate effect of Nano- CaCO_3 particles can also fill pores and capillary voids, improving the structure of the concrete and increasing its compactness, ultimately contributing to enhanced compressive strength. However, as the quantity of Nano- CaCO_3 increases, it may gather together and fail to disperse uniformly throughout the slurry, thereby decreasing the strength of the test block. Incorporating ceramsite as the aggregate of autoclaved aerated concrete can significantly boost the compressive strength of the test block, even surpassing that of the group with 1% Nano- CaCO_3 . Based on the test results and SEM images, it can be inferred that during the mixing and stirring process, some of the cement was absorbed into the pores of the ceramsite surface, resulting in a low water–cement ratio cement slurry. Upon hardening, the cement stone forms a solid structure, tightly wrapping around the outer surface of the aggregate. It is also embedded in the ceramsite through the aggregate’s pores, forming a “locking structure”, which provides higher strength to the overall system.

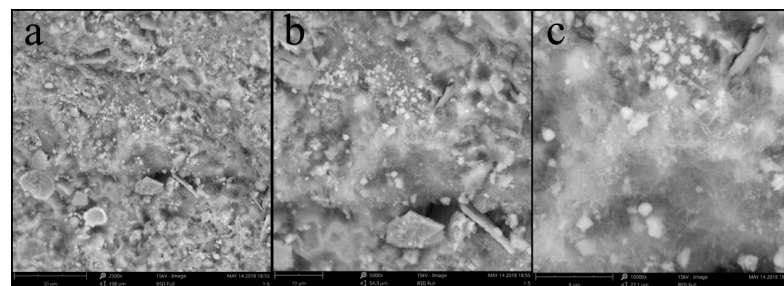


Figure 6. Ordinary autoclaved aerated concrete test block. ((a): $\times 2500$; (b): $\times 5000$; (c): $\times 10000$).

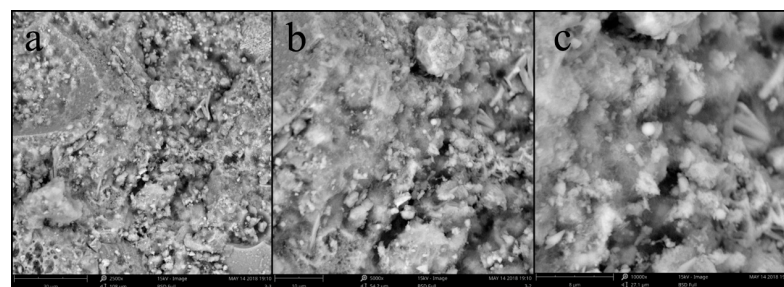


Figure 7. Nano- CaCO_3 autoclaved aerated concrete test block. ((a): $\times 2500$; (b): $\times 5000$; (c): $\times 10000$).

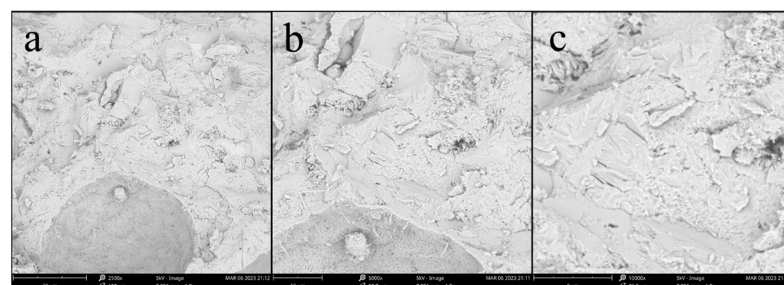


Figure 8. Ceramsite autoclaved aerated concrete test block. ((a): $\times 2500$; (b): $\times 5000$; (c): $\times 10000$).

4. Conclusions

This paper aimed to study and verify the feasibility of the sustainable industrial method of recycling silt into building materials through the process of “dewatering silt-firing ceramsite-preparing concrete blocks”. The influence of flocculant dosage and dehydration time on dehydration effect, and the strength study of ceramsite autoclaved aerated concrete block were studied, and conclusions are as follows:

- (1) The optimal flocculation time is 90 min, and a dosage of less than 0.6 g/500 mL led to increasing water removal as the dosage increased. However, for dosages greater than 0.6 g/500 mL, the dehydration amount decreased with increasing dosage. Considering cost and the required viscosity for ceramsite preparation, the optimal dosage of Wei flocculant was determined to be 0.8 g/L.
- (2) Nano- CaCO_3 improves compressive strength by promoting hydration and filling pores, with 1% being the optimal amount resulting in a 44.4% improvement in strength. However, increasing the amount of Nano- CaCO_3 led to agglomeration, which reduced compressive strength. By contrast, adding 20% ceramsite resulted in a 49.8% increase in compressive strength, surpassing the effect of 1% Nano- CaCO_3 .
- (3) “Dehydration of silt-firing ceramsite-preparing concrete blocks” is a feasible method for recycling silt. It can effectively treat a large amount of sludge which causing environmental pollution, and transform it into building materials with excellent performance.

Author Contributions: J.Z.: Data curation, Writing—Original draft preparation; C.P.: Statement of Conceptualization, Methodology; Y.H.: Writing—Reviewing and Editing; S.Q.: Writing—Reviewing and Editing. All authors have read and agreed to the published version of the manuscript.

Funding: The authors gratefully acknowledge the Natural Science Foundation of Zhejiang Province (Grant No. LGG21E080006, Investee: Chonggen Pan), the Science and Technology project of the Ministry of Housing and Urban Rural Development (2021-k-117, Investee: Chonggen Pan), Ningbo 2025 Science and Technology Major Project (Grant No. 2019B10049, 2020Z035, 2020Z040, Investee: Chonggen Pan).

Data Availability Statement: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request. All data, models, and code generated or used during the study appear in the submitted article.

Conflicts of Interest: In this paper, the authors declared that they have no conflict of interest related to this work, nor any commercial or associative interests that represent potential conflicts of interest in connection with the work submitted.

References

1. Kenneth, W.C. Prediction of Consolidation of Very Soft Soiln. *J. Geotech. Eng.* **1984**, *110*, 775–795.
2. Zhu, Y.; Jin, X.; Fang, H. Discussion on the application of mud-filled pipe bag technology. *Tech. Text.* **2000**, *6*, 36–38.
3. Yang, G. *Technical Guide for Application of Geosynthetics Reinforced Earth Structures*; China Communication Press: Beijing, China, 2016.
4. Wu, S.; Yan, Y.; Sun, P. Properties and preparation technology of high strength silt ceramsite lightweight aggregate. *Bull. Chin. Ceram. Soc.* **2018**, *37*, 2395–2399.
5. Guo, J.; Chen, C. Sludge conditioning using the composite of a bioflocculant and PAC for enhancement in dewaterability. *Chemosphere* **2017**, *185*, 277–283. [[CrossRef](#)]
6. Wu, W.; Ma, J.; Xu, J.; Wang, Z. Mechanistic insights into chemical conditioning by polyacrylamide with different charge densities and its iMPacts on sludge dewaterability. *Chem. Eng. J.* **2021**, *410*, 128425. [[CrossRef](#)]
7. Chen, Q.; Wang, Y. Influence of single- and dual-flocculant conditioning on the geometric morphology and internal structure of activated sludge. *Powder Technol.* **2015**, *270*, 1–9. [[CrossRef](#)]
8. Li, Q. *Study on the Preparation of Bioflocculant and Its Flocculation Effect on Cyanobacteria in Chaohu Lake*; Hefei University: Hefei, China, 2020.
9. Tao, Y.; Fu, K. Development and progress of aerated concrete in China. *New Build. Mater.* **2003**, *7*, 16–19.
10. Tu, F. Current Situation and Development Tendancy of Building Energy Conservation. *Hous. Sci.* **2004**, *9*, 8–11.
11. Narayanan, K.; Ramamurthy, K. Structure and properties of aerated concrete: A review. *Cem. Concr. Compos.* **2000**, *22*, 321–329. [[CrossRef](#)]
12. Sengupta, J. Development and application of light weight aerated concrete blocks from fly ash. *Indian Concr. J.* **1992**, *66*, 383–387.

13. Mitsuda, T.; Sasaki, K.; Ishida, H. Phase Evolution during Autoclaving Process of Aerated Concrete. *J. Am. Ceram. Soc.* **2010**, *75*, 1858–1863. [\[CrossRef\]](#)
14. Yang, E.H.; Liu, Y.Q.; Chen, Z.T. Environmental Sustainability through Recycling Incineration Bottom Ash for the Production of Autoclaved Aerated Concrete. *Key Eng. Mater.* **2015**, *650*, 20. [\[CrossRef\]](#)
15. El-Hemaly, S.A.S.; Taha, A.S.; El-Didamony, H. Influence of slag substitution on some properties of sand-lime aerated concrete. *J. Mater. Sci.* **1986**, *21*, 1293–1296. [\[CrossRef\]](#)
16. Sun, B.; Li, G.; Jia, C. Relationship between hydration products, strength and shrinkage of autoclaved aerated concrete. *J. Chin. Ceram. Soc.* **1983**, *1*, 79–86+134–136.
17. Shao, J. *Study on the Preparation and Properties of Recycled Concrete using Recycled Aggregate*; Guangxi University: Nanning, China, 2013.
18. Wang, D.; Wang, Y. Study on moisture content and frost resistance of desert sand autoclaved aerated concrete. *Concrete* **2018**, *7*, 137–140.
19. Zhang, H. Experimental study of concrete resisting to freeze-thaw damage. *Northwest Water Resour. Water Eng.* **2001**, *1*, 49–52.
20. Peng, J. *Study on The Forming, Characterization and Effect of Autoclaved Aerated Concrete Pores*; Chongqing University: Chongqing, China, 2011.
21. Li, P.; Jing, P.; Geng, J.; Chen, G. Numerical Simulation of Equivalent Thermal Conductivity of Autoclaved Aerated Concrete. *J. North China Univ. Water Resour. Electr. Power* **2018**, *39*, 91–96.
22. Cui, J.; He, W.; Liao, S.; Xia, X. Measuring and Analysing Techniques of Structural Features for Porous Materials Research. *Mater. Rep.* **2009**, *23*, 82–86.
23. Zhou, S.; Lu, Z.; Yan, Y. Study on Thermal Conductivity Model of Foamed Concrete. *Mater. Rep.* **2009**, *23*, 69–73+83.
24. Qian, X.; Qiu, Y.; Zhan, S. Self-insulation system for external wall of ceramsite reinforced aerated block. *New Build. Mater.* **2007**, *34*, 56–58.
25. GB11968-2006; Autoclaved Aerated Concrete Blocks. Standards Press of China: Beijing, China, 2006.
26. Wei, Y.; Wang, Y. Study on the Aerated Concrete Block Prepared by Silicon Tailing Ceramsite. *Bull. Chin. Ceram. Soc.* **2018**, *37*, 2336–2340+2345.
27. Hou, X. *Study on the Properties of Light Iron Tailings Ore Ceramsite Concrete for Structural Use*; Chang'an University: Xi'an, China, 2021. [\[CrossRef\]](#)
28. Matsui, K.; Kikuma, J.; Tsunashima, M.; Ishikawa, T.; Matsuno, S.Y.; Ogawa, A.; Sato, M. In situ time-resolved X-ray diffraction of tobermorite formation in autoclaved aerated concrete: Influence of silica source reactivity and Al addition. *Cem. Concr.* **2011**, *41*, 2066–2074. [\[CrossRef\]](#)
29. Wang, S.; Yang, L.; Ma, X.; Mei, R.; Li, C.; Sun, Z. The formation of porous light ceramsite using Yellow River sediment and its application in concrete masonry production. *Case Stud. Constr. Mater.* **2022**, *17*, e01340. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.