SCIENCE LETTERS

Available online at http://myjms.mohe.gov.my/index.php/sl

ISSN: 1675-7785
eISSN: 2682-8626

Science Letters 18(3) 2024, 10-16.

A Study on Feasibility of Untreated Sea Sand in Producing Lightweight Tiles

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ARTICLE INFO

Article history:
Received 19 July 2024
Revised 1 August 2024
Accepted 28 August 2024
Online first
Published 10 October 2024

Keywords:
Chloride Content,
Lightweight Tile,
Physical Properties,
Chemical Properties,
Untreated Sea Sand

DOI:
10.24191/scl.v18i4.6782

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ABSTRACT

This study examines the potential of using sea sand as a starting material to produce silica-based products. Preliminary characterization of sea sand is done to identify physical and chemical properties for use in various products. The results found that sea sand has a high purity of 91.69% Silicone oxide (SiO_2) content. In addition, the content of sea sand has a content of Iron (III) oxide (Fe_2O_3), Alumina oxide (Al_2O_3), Potassium oxide (CaO), Potassium oxide (K_2O), Sodium oxide (Na_2O), Magnesium oxide (MgO), and Titanium dioxide (TiO_2). The present findings indicated that the untreated sea sand, via wet assays analysis, contained 95.10% of silica grade. XRD analysis showed the main phase of SiO_2 in crystalline form (PDF 01-085-0794). Simultaneous Thermal Analysis (STA) observation showed that the sea sand sample was relatively stable up to 1200 °C with the detection of the exothermic peak that suggested a crystallization of a new phase, namely melilite, at 1034 °C to 1148 °C.

INTRODUCTION

Traditionally, commercial ceramic tile manufacturing is produced using 100% natural mineral resources and processed at temperatures exceeding 1100 °C. The continuous use of natural minerals will cause a reduction in mineral resources and cause the price of these raw materials to become more expensive. The high cost of raw materials will affect the viability of development projects and greatly impact the construction sector. To overcome this problem, ceramic glass tile products based on industrial waste have been produced using a low temperature below 1000 °C. In addition to low temperatures, manufacturing costs can be reduced by 50%.

The use of sea sand is also used as a substitute for the main ingredient of silica sand. Sea sand is also used in various applications, such as in the concrete manufacturing industry [1,2] and composite materials [3]. The results found that the use of sea sand in concrete that has been treated has a strong strength compared to river sand. There are several methods to remove chloride salt on the surface of the sea sand, such as the washing method, the immersion method, and the heating method up to the boiling point. In this study, the use of untreated sea sand is used to reduce the cost of purifying sea sand. Using industrial waste in manufacturing glass-ceramic tiles can reduce waste and its negative environmental effects. Furthermore, it could minimize the ceramic industry's reliance on natural mineral resources such as kaolin and feldspar for ceramic production.

The production of lighter ceramic glass tiles with existing mechanical and physical strength can be processed using specific formulations, such as foaming agents. Foaming agents can produce porous ceramic glass tiles. Another definition of the word porous is that which is hollow, perforated, and not dense. Pore foaming agents have been widely studied, including polymer particles, starch, carbon black, and biomass. Other researchers have reported using wood waste and sawdust as foaming agents in ceramic tiles to produce light two-layer porcelain stoneware tiles [4]. The results show that the combination of sawdust can reduce the product's weight by up to 7.5% and maintain its mechanical strength compared to commercial stoneware tiles, which the porous porcelain samples prepared with 5-20 wt.% Poly methyl methacrylate (PMMA) and sintering at 1300°C exhibited flexural strength of 36-56 MPa, exceeding the ISO 13006 standard minimum strength for ceramic tiles [5]. This research work studied the feasibility of untreated sea sand for producing lightweight tiles.

EXPERIMENTAL

Sea sand samples were obtained from five different Pahang coastline regions. Sample was dried in an oven at a temperature of 60 °C for 8 hours to remove the moisture content in it. After that, sampling process was done using cone quartering procedure. The cone and quartering method were employed to divide the bulk of the feed sample into smaller batches. A conical heap was formed by dumping a shovel full of sea sand on the cone's peak, ensuring that the pieces that slide down the sides were spread as equally as possible and that the centre of the cone remained stable. To ensure equally scattered particles, the technique was done several times. Gravimetric analysis, XRF analysis, and XRD were prepared for evaluating untreated sea sand. The chemical composition was assessed by means of X-ray fluorescence (XRF) with a wavelength-dispersive spectrometer (Shimadzu, 1700 model). Using platinum crucibles and a controlled environment, Simultaneous Thermal Analyze (STA) (Linseis Model, Sta Pt 1600) has been used to ascertain the thermal behavior of the raw materials.

RESULTS AND DISCUSSION

Higher contains SiO_2 influences the quality of lightweight tiles

Table 1 shows the untreated sea sand comprised of silica (SiO_2), iron oxide (Fe_2O_3), alumina (Al_2O_3), calcium oxide (CaO), potassium oxide (K_2O), sodium oxide (Na_2O), magnesium oxide (MgO), and titanium oxide (TiO_2). Along with sodium and chloride, the sea sand also contains substances and shells [6]. Table 1 indicates the chemical compositions of various untreated sea sand samples 1, sample 2, sample 3, sample 4, and sample 5 as labeled. X-ray Fluorescence (XRF) examination showed that the untreated sea sand sample comprised eight main oxide compounds.

XRF analysis was used as an estimation result to determine the major chemical compositions in terms of oxide elements of the sea sand sample. Sample 1 had the highest silica content of 92%. As reported by previous research, sea sand with high silica content commonly contains low or no calcium oxide. In contrast, the sea sand with high calcium concentration, such as sample 1 tested, had a lower silica content. From this situation, it can be concluded that the geological location influenced the mechanical and chemical profile of sea sand [7].

https://doi.org/10.24191/scl.v18i4.6782

Table 1: The percentage of untreated sea sand's chemical composition at every coastal location (%).

Samples	SiO_2	Fe_2O_3	Al_2O_3	CaO	K_2O	Na_2O	MgO	TiO_2	Loss of ignition (LOI)
1	91.69	0.99	0.89	1.56	0.21	0.79	1.59	0.06	2.17
2	83.71	1.67	1.29	4.89	0.33	0.79	1.63	0.08	5.56
3	90.68	0.48	0.85	2.46	0.30	0.83	1.42	0.05	2.88
4	75.00	4.06	2.86	4.74	0.92	1.20	3.86	0.39	6.92
5	85.02	1.69	3.79	1.46	0.96	1.23	1.7	0.28	3.79

Figure 1. Untreated sand was found in the different coastline regions of Pahang Island.

Gravimetric analysis of untreated sea sand

Figure 2 reveals the assay reports for untreated silica sand. Wet assay gravimetric analysis determined the silica (SiO_2) content. The wet approach is comparatively more precise and better for determining silica content. Due to the gravimetric method's simplicity, speed, and precision in determining SiO_2 in a sample of sea sand, it was chosen. The earlier research's gravimetric examination of the sugarcane waste ash proved that the SiO_2 content ranged between 88.68 % and 99.08 % [8]. The optimum recovery of silica grade from sample 1, according to Figure 2, is 95.10%. A 4% disparity between the SiO_2 contents determined by gravimetric measurement (Figure 2) and XRF analysis (Table 1) was noted. In contrast to gravimetric analysis, which dissolves all the sample's minerals, XRF analysis concentrates its target region more on the sample's surface. The principal chemical compositions of the sample in terms of oxide elements can be estimated using the results of XRF analysis.

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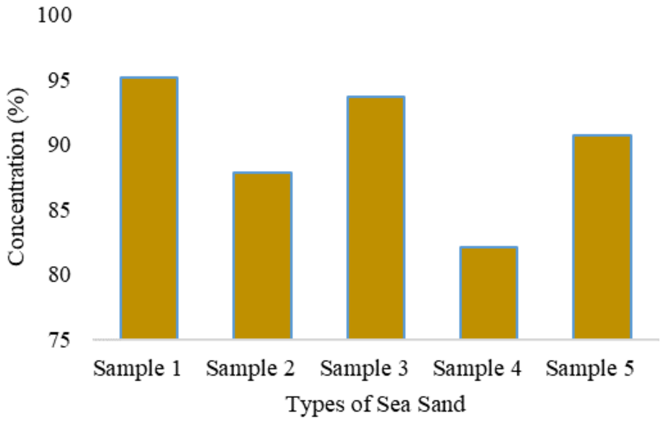

Figure 2: Wet assay analysis of SiO_2.

Thermal Analysis influences the production of lightweight tile

The study uses the Differential Scanning Calorimetry-Thermo gravimetric (DSC-TG) instrument for Simultaneous thermal analysis (STA) of loess untreated sea sand. It identifies common features like water loss, hydroxides, mater decomposition, quartz transformation, and chemical reactions, with varying intensity in each sample in Figure 3.

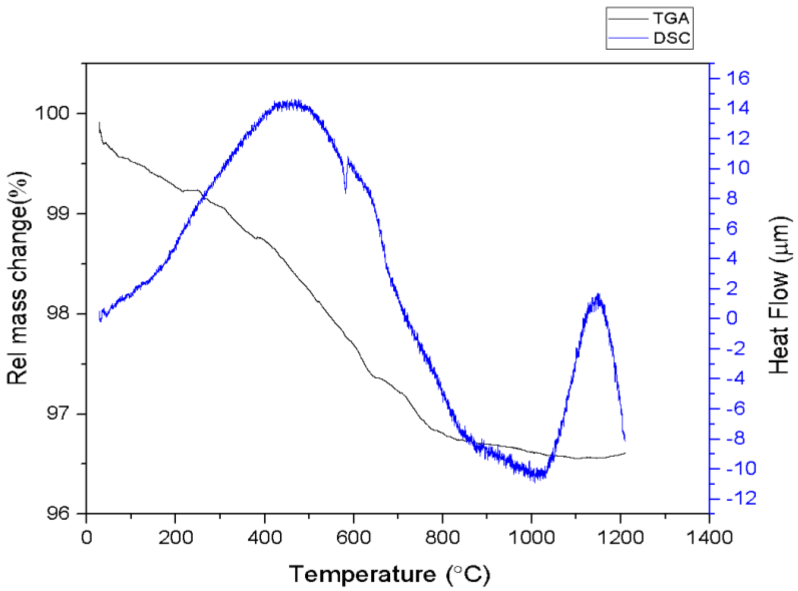

Figure 3: STA of untreated sea sand for highest silica content using sample 1.

https://doi.org/10.24191/scl.v18i4.6782

The DSC curves of untreated sea sand revealed three endothermic peaks at 30.2 ºC, 43.7 ºC, 575 ºC, and 867 ºC, indicating the allotropic transition of Quartz SiO_2-α to SiO_2-β. The first peak at 30.2 ºC and 43.7 ºC may be due to water release from sand particles. The third peak at 575 ºC reveals the α to β Quartz transformation, while the fourth peak at 867 ºC indicates the β quartz transformation to tridymite. Previous research found an endothermic peak of about 570ºC on DSC curves of concrete due to phase change in siliceous sand samples [9]. Silica transforms α-quartz, β-quartz, HP-tridymite, and β-cristobalite when heated. At 870°C, reactions occur, while at 1000°C, pure quartz remains. With K_2O, quartz transformation begins at the quartz/glass interface, forming cristobalite. However, cristobalite becomes metastable at 1000°C and 1200°C, transforming into tridymite as temperature increases, as reported in previous studies [10]. The exothermic peak at 1051°C, possibly indicating the crystallization of a new mellite phase, was observed at temperatures ranging from 1034°C to 1148°C [11]. Melilite was formed by heating with the highest CaO content and adding elements like Ca, Na, Mg, Al, Fe, Si, and Al.

The study found that increasing the heating temperature to 1300 °C led to a gradual weight reduction in untreated sea sand samples. The weight loss was 0.2% at 37 °C and 1.7% at 586 °C. This loss may be due to moisture evaporation from the samples at higher temperatures, which occurred in two stages at lower temperatures below 200 °C and higher temperatures above 500 °C. Decomposition of the adsorbed water was detected between 450 °C and 550 °C and 700 °C to 850 °C as mentioned in previous research in the river sand sample [12]. This phenomenon was noticed in untreated sea sand samples in Figure 3. After the moisture evaporation, no further mass losses were noticed.

X-ray diffraction (XRD) analysis

Figure 4 illustrates the diffraction pattern of untreated sea sand, revealing a single peak of SiO_2 at 26.64° of 2θ. An amorphous hump was seen between 37° and 40°, which might be attributed to the existence of amorphous glassy material. The highest peak diffraction (0,1,1) corresponds to silicates present in both forms of untreated sea sand. In contrast, the low-intensity peaks can be assigned to other metal oxides in the untreated sea sand. The pattern was identified in the aggregate as hexagonal, related to the SiO_2 crystalline phase corresponding to the file [PDF 01-085-0794] [13]. The peaks, referred to as quartz phase crystals, are presented in all the existing peaks, as shown in Figure 4. The diffraction pattern revealed that this untreated sea sand was crystalline in structure. In an earlier study, raw sea sand showed greater crystallinity, as demonstrated by the number of crystalline peaks in the diffractogram in Figure 5 [14].

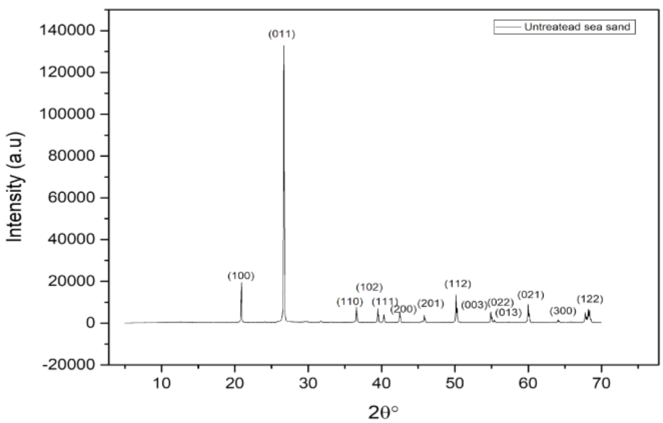

Fig 4. XRD of untreated sea sand using sample 1

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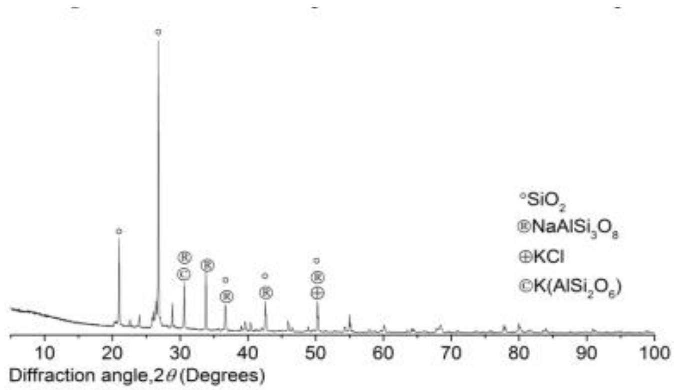

Figure 5. XRD patterns of sea sand.

Figure 5. XRD pattern of untreated sea sand

CONCLUSION

In this study, untreated sea sand had a high potential to replace silica sand for lightweight tile production based on untreated sea sand's physical and chemical properties. As an XRF and gravimetric analysis result, the contents of untreated sea sand, including 91.69% of SiO_2, 0.99%, Fe_2O_3, 0.89% of Al_2O_3,1.56% of CaO, 0.21% of K_2O, 0.79% of Na_2O, 1.59% of MgO, and 0.06% of TiO_2 were the predominant phases in the untreated sea sand. From the wet assay method, the untreated sea sand taken from sample 1 location typically had the maximum silica purity of around 95.10% with crystalline in SiO_2 structure. Quartz's phase transition of SiO_2-α to SiO_2-β was detected at 575 °C by using STA analysis. Besides that, an exothermic peak represented the crystallization of the new mellite phase at temperatures between 1034 ^{o}C and 1148 ^{o}C.

ACKNOWLEDGEMENTS

Senior Director of the Mineral Research Centre of Malaysia's Mineral and Geoscience Department is acknowledged for his ongoing assistance in completing this research project and writing the technical paper. The authors would like to express their heartfelt gratitude. The authors would also like to thank the Mineral Research Centre's support staff for their constant counsel and help.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Syarifah Aminah carried out the research and wrote and revised the article. Mohd Idham and Mohd Hakim conceptualized and validated the central research idea and provided the theoretical framework. Nabihah managed project administration, supervised research progress, anchored the review and revisions, and approved the article submission. All authors have read and agreed to the published version of the manuscript.

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