STUDY ON THE USE OF SEA SAND AND SEAWATER IN GEOPOLYMER CONCRETE PRODUCTION IN HA TIEN CITY, KIEN GIANG PROVINCE

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(Received: September 15, 2024; Revised: October 02, 2024; Accepted: October 15, 2024)

DOI: 10.31130/ud-jst.2024.536E

Abstract - The article investigates the potential of using sea sand and seawater from Ha Tien City, Kien Giang Province, in geopolymer concrete production. Geopolymer concrete is an environmentally friendly material that can help reduce greenhouse gas emissions while utilizing locally available resources. The study evaluates the mechanical and chemical properties of sea sand and seawater as alternatives to river sand and freshwater, with the goal of identifying sustainable concrete production methods. The results indicate that using marine sand and seawater does not compromise the compressive strength of the concrete and may even slightly improve it in some cases. This presents both economic, environmental benefits, and opens up opportunities for wider application in Vietnam's construction industry.

Key words - Sea sand; seawater; Geopolymer concrete; fly ash; compressive strength.

1. Introduction

Geopolymer concrete has gained attention as a promising sustainable building material due to its potential to reduce CO_2 emissions and utilize industrial by-products. Given the depletion of river sand resources and the growing environmental concerns associated with sand extraction, research into alternative materials has intensified. Sea sand and seawater have emerged as viable substitutes in geopolymer concrete production, with studies showing they can partially or fully replace river sand and freshwater, though certain challenges still need to be addressed [1-5].

Numerous international studies have examined the benefits and limitations of incorporating sea sand into geopolymer concrete. For instance, Du Pan et al. suggest that sea sand can enhance the early-age compressive strength of concrete but may lead to a slight reduction in compressive strength at 28 days [6]. Similarly, Alaa M. Rashad's research explored the impact of replacing river sand with sea sand in inappropriate proportions, which could lead to a decrease in compressive strength [7].

Seawater, with its high sodium and chloride ion content, also plays a role in influencing the polymerization process and the mechanical properties of geopolymer concrete. Research indicates that seawater can partially substitute freshwater, helping to maintain high compressive strength and durability, particularly in marine environments, due to the alkaline conditions it provides [1, 2, 8].

In Vietnam, recent studies have started to investigate the use of sea sand and seawater in geopolymer concrete production. These studies have shown that sea sand can replace river sand without significantly reducing compressive strength, while also improving corrosion resistance in marine environments [9-11].

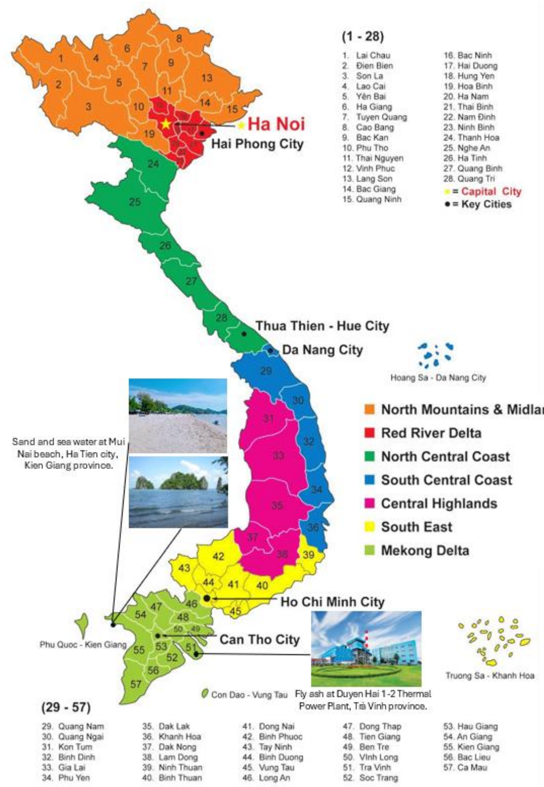


Figure 1. *Origin of sea sand, seawater, and fly ash*

This paper specifically examines the potential use of sea sand and seawater from the Ha Tien City area, Kien Giang Province (Figure 1), as substitutes for river sand and freshwater in geopolymer concrete production. The binder used in this study consists of fly ash combined with an alkaline solution (NaOH and Na_2SiO_3), forming a geopolymer mix with high mechanical properties. Two binder-to-aggregate ratios, 25% and 35%, were tested to evaluate their effect on the concrete's mechanical properties. Additionally, the fly ash content in the binder was varied at 10%, 15%, and 20% to assess its impact on the compressive strength of the geopolymer concrete. The results of this research will provide a scientific foundation for using sea sand and seawater in construction technologies, contributing to the preservation of freshwater and river sand resources.

2. Methodology

2.1. Materials

2.1.1. Fine Aggregates

This study used two types of sand: river sand, which is commonly used for concrete production, and marine sand collected from Mui Nai Beach, Ha Tien City, Kien Giang Province (Figure 2). The fineness modulus of the river sand is 2.32, and the particle size distribution is shown in Table 1. These parameters meet the requirements for concrete sand specified in 7570:2006 standard [12].

Figure 2. *Marine sand from Mui Nai Beach, Ha Tien City, Kien Giang Province*

For marine sand, samples were collected both from the shoreline and below the water surface. This sand contained other materials, such as shell fragments. After collection, the sand was dried on the beach and then transported to the laboratory. The sand was sieved using a 5 mm mesh to remove particles larger than 5 mm. The technical properties of the marine sand are presented in Table 2, and the particle size distribution is shown in Table 3.

Table 1. *Particle size distribution of river sand*

Sieve Size (mm)	2.5	1.25	0.63	0.315	0.14
Cumulative Residue (%)	0.98	22.76	35.65	77.23	95.66

Table 2. *Technical properties of marine sand*

No.	**Parameter**	**Unit**	**Result**	**Test Standard**
1	Specific Gravity	g/cm^3	2.65	7572-4:2006
2	Compacted Bulk Density	g/cm^3	1.49	7572-4:2006
	Loose Bulk Density		1.36	
3	Water Absorption	%	2.27	7572-4:2006
4	Chloride Ion Content (Cl^-)	%	0.3	7572-15:2006
5	SO_3 Content	%	0.01	7572-16:2006
6	Modulus		2.537	7572-2:2006

Table 3. *Particle size distribution of marine sand*

Sieve Size (mm)	**Individual Residue (%)**	**Cumulative Residue (%)**
5	0	0
2.5	1.4	1.4
1.25	18.6	20
0.63	32	52
0.315	32.6	84.6
0.14	11.1	95.7
Pan	4.17	99.87

2.1.2. Alkaline Activator

The alkaline activating solution used in the experiment was a mixture of sodium hydroxide (NaOH) and sodium silicate solution (Figure 3).

The NaOH alkaline solution was prepared by dissolving anhydrous NaOH in water. The anhydrous NaOH was in the form of white flakes, with a purity of 97-98% and a specific gravity of 2.130 g/cm^3. When mixed with water, the alkaline solution releases significant heat. The amount of solid NaOH depends on the concentration of the NaOH solution being used. In this experiment, a 16M NaOH solution was utilized.

The sodium silicate solution used in the experiment had the following chemical composition: Na_2O = 11.9%, SiO_2 = 29.7%, insoluble residue = 0.02%, with the remaining being H_2O = 58.4%. The solution had a silica modulus of 2.57, a density of 1.48 g/ml, and was a clear, odorless, white liquid.

Figure 3. *NaOH và Na_2SiO_3*

2.1.3. Fly Ash

The fly ash used in the experiment was sourced from the Duyen Hai 1-2 Thermal Power Plant in Tra Vinh Province, which utilizes traditional large-scale technology and coal fines from the Quang Ninh region. The fly ash obtained was of relatively good quality, meeting all the requirements of ASTM-C618 standards.

The test results showed that the combined percentage of (SiO_2 + Al_2O_3 + Fe_2O_3) exceeded 70%, while CaO was less than 15%. This complies with the fly ash standard as per ASTM C618 [13], confirming that the fly ash used in the experiment was of acceptable quality.

2.1.4. Seawater

Seawater was collected from the coastal area of Ha Tien, Kien Giang Province, approximately 5 meters from the shoreline. The chemical composition of the seawater is presented in Table 4.

Table 4. *Chemical composition of seawater*

No.	Parameter	Unit	Result	Standard/ Method
1	pH at 25°C		7.9	6492:2011 [14]
2	Chloride content (Cl^-)	mg/L	$18.8x10^3$	SMEWW 2012
3	Sulfate content (SO_4^{2-})	mg/L	$2.8x20^3$	SMEWW 2012
4	Sodium content (Na)	mg/L	$11.5x10^3$	SMEWW 2012
5	Magnesium content (Mg)	mg/L	$1.2x10^3$	SMEWW 2012

2.2. Geopolymer Concrete Mixtures

Binder: Fly ash is combined with an alkaline solution (NaOH and Na_2SiO_3) to create the geopolymer mixture. The activating solution used in the experiment triggers the geopolymerization process in the concrete. This solution is a combination of NaOH and Na_2SiO_3, with a mass ratio of Na_2SiO_3 to NaOH of 2.5.

The geopolymer concrete mix design follows the guidelines provided by Rangan [15]. The concrete was prepared under two conditions where the binder accounted for 25% and 35% of the total mix volume. In the binder mixture, the fly ash content was 10%, 15%, and 20%, respectively (Table 5).

Table 5. *Composition of Geopolymer Concrete Mix*

Mixture	Binder Ratio (%)	Fly Ash		Alkaline liquid		River sand (marine sand) (kg)	Aggregates (kg)	Water (Freshwater/Seawater) (liters)
		Fly Ash (%)	Fly Ash (kg)	NaOH (kg)	Na_2SiO_3 (kg)			
CP1	25%	10%	60	154.3	385.7	540	1260	85.8
CP2	25%	15%	90	145.7	364.3	540	1260	81.0
CP3	25%	20%	120	137.1	342.9	540	1260	76.2
CP4	35%	10%	84	216.0	540.0	440	1120	120.1
CP5	35%	15%	126	204.0	510.0	440	1120	113.4
CP6	35%	20%	168	192.0	480.0	440	1120	106.7

2.3. Sample Preparation and Compressive Strength Testing

Figure 4. *Concrete Mold*

Table 6. *Compressive strength of concrete at 28 days*

Mixture	Binder Ratio (%)	Fly Ash (%)	Compressive strength (MPa)	
			River sand and freshwater	Marine sand and seawater
CP1	25%	10%	23.9	25
CP2	25%	15%	27.4	27.9
CP3	25%	20%	30.3	31.8
CP4	35%	10%	28.6	31.7
CP5	35%	15%	30.9	35.9
CP6	35%	20%	32.9	41.1

The experimental specimens are 15 cm cubic samples, as shown in Figure 4, with each set consisting of three samples. Since geopolymer concrete made from fly ash does not harden immediately at room temperature, the samples required heat treatment after fabrication. They were dried at 90°C for 20 hours, followed by curing under laboratory conditions at a recorded temperature of 25±2°C and humidity of 75±7%. At the designated testing ages, the samples underwent compression testing to determine their compressive strength, as presented in Table 6.

3. Results and Discussion

3.1. Influence of Marine Sand and Seawater on the Compressive Strength of Geopolymer Concrete

The chart compares the compressive strength of geopolymer concrete made with river sand and freshwater against concrete made with marine sand and seawater across six different mixtures (CP1 to CP6) (Figure 5).

In every case, the concrete using marine sand and seawater exhibits higher compressive strength, with the strength difference becoming more pronounced in mixtures with higher binder content. The smallest differences are seen in CP1 and CP2, while CP6 shows the most significant increase (41.1 MPa compared to 32.9 MPa). This suggests that the combination of marine sand and seawater may produce a synergistic effect, particularly as the binder content rises. The overall improvement in compressive strength with marine sand and seawater is likely due to their chemical compositions, which seem to enhance the geopolymerization process.

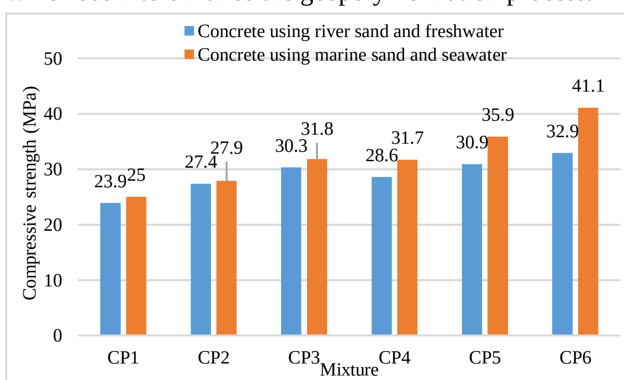


Figure 5. *Compressive Strength of Concrete Using Marine Sand and Seawater Compared to Concrete Using River Sand and Freshwater*

3.2. Influence of binder ratio and Fly Ash content on the Compressive Strength of Geopolymer Concrete

3.2.1. Influence of binder ratio

The chart shows the influence of binder ratio (25% vs. 35%) on the compressive strength of geopolymer concrete across six different mixtures (Figure 6). It is clear that the concrete with a higher binder ratio (35%) consistently demonstrates superior compressive strength compared to the 25% binder ratio for all mixtures. This result is consistent with other studies on the influence of binder content on the compressive strength of concrete [16, 17].

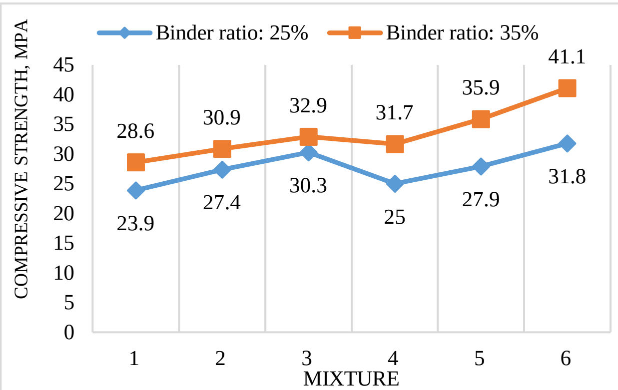


Figure 6. *Compressive Strength of Concrete with Varying Binder Ratios*

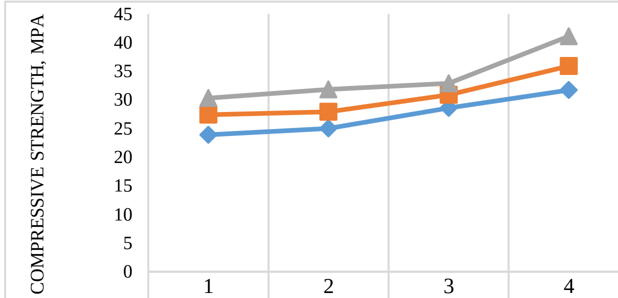
At the beginning, in Mixture 1, the compressive strength for the 25% binder ratio is 23.9 MPa, while the 35% binder ratio reaches 28.6 MPa. This trend continues, with a slight dip in Mixture 4 for the 25% binder ratio (25 MPa), compared to the relatively stable 35% binder ratio (31.7 MPa). The strength difference becomes most pronounced in Mixture 6, where the 35% binder ratio achieves a peak value of 41.1 MPa, whereas the 25% binder ratio reaches only 31.8 MPa.

In geopolymer concrete, increasing the binder ratio typically results in higher compressive strength because a greater amount of binder leads to a more intense geopolymerization process. This process creates a stronger structure through the formation of polymeric bonds, contributing to a denser and more durable concrete matrix. Specifically, with more binder, the amount of aluminosilicate released from fly ash or slag increases, which then reacts with the alkaline solution, producing more geopolymer gel and improving the microstructure of the concrete.

3.2.2. Influence of Fly Ash content on the Compressive Strength of concrete

Figure 7 illustrates the effect of varying fly ash content (10%, 15%, and 20%) on the compressive strength of geopolymer concrete across different mixtures. As seen from the graph, increasing the fly ash content consistently improves the compressive strength of the concrete.

For the mixture with 10% fly ash, the compressive strength starts at 23.9 MPa in Mixture 1 and gradually rises to 31.7 MPa in Mixture 4. Meanwhile, for the 15% fly ash content, the strength increases from 27.4 MPa in Mixture 1 to 35.9 MPa in Mixture 4. The most significant improvement is observed with 20% fly ash, where the compressive strength jumps from 30.3 MPa in Mixture 1 to a maximum of 41.1 MPa in Mixture 4.



	1	2	3	4
10%	23.9	25	28.6	31.7
15%	27.4	27.9	30.9	35.9
20%	30.3	31.8	32.9	41.1

Figure 7. *Compressive Strength of Concrete with varying Fly Ash ratios*

This trend demonstrates that higher fly ash content contributes to enhanced geopolymerization, leading to a stronger matrix and higher compressive strength. The larger amount of fly ash provides more aluminosilicate material for the reaction, resulting in increased geopolymer gel formation, which improves the overall structural integrity of the concrete.

4. Conclusion

The study confirms that both the binder ratio and fly ash content have a significant impact on the compressive strength of geopolymer concrete. Under the specific conditions of this research, marine sand and seawater outperformed river sand and freshwater, especially at higher binder ratios, likely due to enhanced geopolymerization. Additionally, increasing the binder ratio from 25% to 35%, along with raising the fly ash content from 10% to 20%, resulted in notable improvements in compressive strength.

In the future, we will fabricate geopolymer concrete using marine sand and seawater with varying binder ratios and fly ash content. The aim of this research is to identify the optimal mix design to enhance the performance and durability of geopolymer concrete in marine environments, while also contributing to the expansion of practical applications for this material.

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