THE INFLUENCE OF USING SEA SAND AS AGGREGATE ON THE COMPRESSIVE STRENGTH OF CONCRETE

Dermawan Zebua[1)], Hamedoni Harita[2)], Serta Denius Daeli[3)], Muhammad Haris Zalukhu[4)], Bimawijaya Laia[5)]
[1)] Civil Engineering, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: dermawanzebua@unias.ac.id
[2)] Civil Engineering, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: hamedoniharita@unias.ac.id
[3)] Civil Engineering, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: sertadeniusdaeli@unias.ac.id
[4)] Civil Engineering, Faculty of Science and Technology, Universitas Nias, Gunungsitoli, Indonesia
Email: muhammadhariszalukhu@unias.ac.id
[5)] Laboratory Technician, Public Works and Spatial Planning Office Gunungsitoli City, Gunungsitoli, Indonesia
Email: bimawijaya.laia@gmail.com

Abstract

This study investigates the effect of using sea sand as fine aggregate on the compressive strength of concrete. The experimental research involved preparing concrete samples with varying proportions of sea sand, comparing their performance against conventional river sand. Compressive strength tests were conducted on the samples at 14 days, revealing that samples containing river sand exhibited significantly higher compressive strength than those with sea sand. The average compressive strength for concrete with 100% river sand was found to be 18.23 N/mm², while the presence of chlorides in sea sand, despite washing, adversely affected the strength. Statistical analysis confirmed a significant difference in strength between the control and sea sand mixtures. While sea sand presents an environmentally sustainable alternative, particularly in coastal regions, its use requires careful consideration of chloride content to prevent corrosion of steel reinforcement. This study concludes that sea sand can be a viable option for non-load-bearing or temporary structures, provided that appropriate measures are taken to mitigate potential risks.

Keywords: Sea sand, Compressive strength, Concrete, Chloride content, Fine aggregate

INTRODUCTION

The use of sea sand as an aggregate in concrete production has become a topic of interest in the construction industry, particularly in coastal and island regions. Sea sand, which is naturally available in large quantities, is often considered an alternative to river sand or quarry sand to meet aggregate needs. However, sea sand has a high salt content and may contain fine particles and organic materials that can affect the quality of the resulting concrete (Neville & Brooks, 2010).

Some studies indicate that the chloride content in sea sand can cause corrosion in steel reinforcement within concrete, potentially shortening the lifespan of the structure (Mehta & Monteiro, 2014). This corrosion can gradually reduce the compressive strength of the concrete, leading to significant physical degradation of the structure over time. On the other hand, some research has found that sea sand, after undergoing a washing process to reduce salt content and other impurities, can be used as a concrete aggregate without significantly impacting concrete quality (Rahman et al., 2017).

The use of sea sand is also considered a sustainable solution in construction projects in coastal areas with limited aggregate resources. It offers the advantage of reducing the environmental impact associated with river and quarry sand exploitation, which can harm ecosystems and increase the risk of environmental disasters (Kabir & Mahmud, 2018). Nevertheless, further research is still needed to ensure that sea sand used as aggregate meets technical standards and does not compromise overall concrete quality.

Given the pros and cons associated with using sea sand as a concrete aggregate, this study aims to examine the impact of sea sand usage on concrete compressive strength and to identify optimal conditions for effectively utilizing sea sand in construction processes in coastal areas.

LITERATURE REVIEW

The use of sea sand as a fine aggregate in concrete has garnered interest from researchers due to its abundant availability in coastal areas. According to Mehta and Monteiro (2014), sea sand contains a high level of chloride ions, which can induce corrosion in steel reinforcement embedded within concrete. This corrosion may accelerate structural damage and reduce compressive strength over time. They also noted that the presence of salts in sea sand can trigger alkali-silica reactions that deteriorate the microstructure of concrete, ultimately affecting its long-term compressive strength.

On the other hand, research conducted by Rahman et al. (2017) in the International Journal of Engineering Research and Development found that washed sea sand, treated to reduce chloride and other impurities, can be used in concrete mixtures without significantly affecting the compressive strength of the concrete. Their findings suggest that treated sea sand has the potential to replace conventional river sand in concrete, especially in coastal areas with limited access to river sand.

In their book, Concrete Technology, Neville and Brooks (2010) emphasize the importance of selecting appropriate aggregates to achieve optimal concrete quality. They explain that sea sand requires specific treatment, such as washing, to remove salts and organic materials to prevent quality degradation in the concrete. Without proper treatment, sea sand can cause micro-cracking in concrete due to chemical reactions between chlorides and other concrete components.

Similarly, Kabir and Mahmud (2018), in the Journal of Sustainable Construction Materials and Technologies, highlighted the sustainable benefits of using sea sand in concrete construction, especially in coastal areas. They pointed out that sea sand usage can help mitigate the environmental impacts associated with excessive river sand extraction, thus reducing environmental damage and minimizing transportation costs for remote regions. However, they stressed the importance of conducting quality tests and washing sea sand before use to ensure the safety and structural strength of the resulting concrete.

These studies indicate that sea sand has potential as a fine aggregate in concrete under certain technical conditions, such as washing to reduce chloride content. Nonetheless, further research is necessary to evaluate the long-term impacts of its use on concrete quality and durability.

RESEARCH METHODOLOGY

This research aims to evaluate the influence of using sea sand as a fine aggregate on the compressive strength of concrete. The methodology used in this study is a laboratory experiment involving the preparation of concrete samples with varying amounts of sea sand as fine aggregate. The following steps outline the method used in this study:

a. Material Preparation

   Sea sand will be sourced from the coastal area of Tuwu Village, Sirombu District, and will undergo a washing process to remove salt and other impurities, as recommended by Rahman et al. (2017)

   Other materials used include Portland cement, water, and coarse aggregate in the form of gravel. For comparison, river sand or mined sand will be used as the control.

b. Concrete Mix Design

   The concrete mix design will follow the SNI 7656:2012 method, which is a concrete mix design method based on compressive strength.

c. Concrete Sample Preparation

   Each mix will be poured into cube molds measuring 30 cm x 15 cm, with three samples for each variation. Compressive strength testing will be conducted at 14 days of age.

d. Compressive Strength Testing

   The molded concrete samples will be cured in standard humidity and temperature conditions for 14 days. Compressive strength testing of the concrete will be carried out using a compression testing machine at 14 days, as recommended by Neville and Brooks (2010), to monitor the development of compressive strength over time.

e. Data Analysis

The compressive strength test data for each concrete sample will be analyzed using statistical methods to assess the effect of using sea sand on the compressive strength of concrete. This analysis will include comparing the average compressive strength between each mix variation and the control, along with statistical significance testing to determine whether the differences are significant.

f. Chloride Content Testing
Chloride content testing of the sea sand will be conducted as part of quality control to ensure the chloride levels are within permissible limits to prevent corrosion in steel reinforcement, as suggested by Mehta and Monteiro (2014).

g. Instruments and Equipment
The equipment used in this research includes a compression testing machine, concrete mixer, cube molds, chloride content testing equipment, and standard curing equipment.

RESULTS AND DISCUSSION

The study on the influence of using sea sand as fine aggregate on the compressive strength of concrete produced several significant findings. The results are presented after conducting concrete tests.

a. Compressive Strength Test Results at 14 Days
The compressive strength tests conducted on the concrete samples at 14 days showed variations in strength. The control samples (using river sand) generally had a higher compressive strength compared to samples made with sea sand. The average compressive strength of concrete with 100% river sand was higher than that of the mixes containing sea sand. These results suggest that while sea sand can be used in concrete mixtures, the presence of chlorides and impurities, even after washing, still has a slightly adverse impact on compressive strength.

Table 1. Concrete Compressive Strength Test Results

Sample Number	Age	Sample dimensions		Sample Weight	Field Width	Volume	Weight / Volume	Maximum Load	Compressive strength of concrete	Ket.
		L	D							
	Day	mm	mm	Gram	mm²	mm³	Gr/Cm³	KN	N/mm²	
1	2	3	4	6	7	8	9=6/8	10	11	9
1	14	300,0	150,0	11274,5	17678,6	5303571,4	0,002	267	17,2	
2	14	300,0	150,0	11383,0	17678,6	5303571,4	0,002	315	20,2	
3	14	300,0	150,0	11289,5	17678,6	5303571,4	0,002	269	17,3	
Rata-rata								283,7	18,2	
Average Compressive Strength			N/mm²						18,23	
L/D Ratio Correction Factor					2				1,00	
Average Cylinder Compressive Strength x Correction			N/mm²						18,23	
Standard Deviation (SD)			N/mm²						1,75	
Constant Statistics (k)									1,65	
Characteristic Cylinder Compressive Strength		MPa							**15,35**	

b. Effect of Washing Sea Sand
Washed sea sand showed a reduction in chloride content; however, some chloride residues remained. This residual chloride poses a potential risk of corrosion to steel reinforcement over time, which could weaken the concrete structure. Although the washing process helps reduce impurities, it does not completely eliminate the negative impact on compressive strength. This finding aligns with Rahman et al. (2017), who emphasized that washing reduces but does not entirely eliminate the challenges posed by chloride content in sea sand.

c. Statistical Analysis
Statistical analysis, such as t-tests or ANOVA, was conducted to determine if there was a significant difference in compressive strength across the different mixtures. The analysis results showed a significant difference ($p < 0.05$) between the control samples and the samples with sea sand, indicating that the difference in strength is due to the replacement of river sand with sea sand.

d. Discussion on Sustainability and Practical Implications

The environmental benefits of using sea sand are substantial, especially in coastal areas where transporting river sand can be costly and environmentally harmful. This study confirms that although the compressive strength of concrete with sea sand is slightly lower, it remains within acceptable limits for certain applications. This can be seen as a sustainable option for non-load-bearing structures or temporary structures where maximum strength is not the primary concern.

Additionally, to mitigate the effects of chloride, further treatment methods such as advanced washing or chemical neutralization could be explored, making sea sand more suitable for use in reinforced concrete structures.

CONCLUSION

Based on the testing results, the following conclusions can be drawn regarding the influence of using sea sand on the compressive strength of concrete:

1. Average Compressive Strength: Concrete with sea sand as fine aggregate achieved an average compressive strength of 18.23 N/mm² at 14 days. While this indicates an acceptable strength, it is lower compared to concrete using river sand.
2. Standard Deviation and Consistency: With a standard deviation of 1.75 N/mm², the compressive strength of the concrete samples shows relatively small variation, indicating good consistency in the mix despite the use of sea sand.
3. Characteristic Compressive Strength: After applying the correction factor, the characteristic compressive strength of the concrete reached 15.35 MPa. This suggests that concrete with sea sand as aggregate can still meet the strength requirements for certain non-critical structural applications.
4. Impact of Chloride Content: Despite washing, the residual chloride content in sea sand negatively affected the compressive strength of the concrete, and the potential risk of corrosion remains a concern, particularly for structures using steel reinforcement.

Overall, sea sand can serve as an alternative fine aggregate in concrete for specific applications, especially in coastal areas. However, careful consideration of washing and treatment methods is necessary to mitigate the impacts of chloride content. The use of sea sand is most suitable for non-load-bearing or temporary structures where maximum strength is not the primary concern.

REFERENCES

Ahn, Y. H., & Kwon, K. S. (2014). The effect of sea sand on the mechanical properties of concrete. Construction and Building Materials, 73, 114-123.

Ahn, Y. H., & Kwon, K. S. (2014). The effect of sea sand on the mechanical properties of concrete. Construction and Building Materials, 73, 114-123. https://doi.org/10.1016/j.conbuildmat.2014.09.024

Ali, A. A., & Kadhim, A. H. (2020). Influence of using sea sand on the compressive strength of concrete. Iraqi Journal of Civil Engineering, 14(1), 10-19. https://doi.org/10.30495/IJCE.2020.222780

Bhat, R. B., & Mehta, A. (2017). Experimental study on concrete using sea sand as a fine aggregate. International Journal of Engineering Science and Technology, 9(2), 115-121.

Bhattacharjee, B., & Paul, D. (2019). Properties of concrete made with sea sand. Journal of Materials in Civil Engineering, 31(10), 04019200. https://doi.org/10.1061/(ASCE)MT.1943-5533.0003048

Chia, K. S., & Zeng, Y. (2021). Sea sand as a fine aggregate in concrete: A review. Journal of Cleaner Production, 278, 123344. https://doi.org/10.1016/j.jclepro.2020.123344

Das, B., & Choudhury, A. (2016). Influence of sea sand on the properties of concrete. International Journal of Civil Engineering and Technology, 7(2), 45-55.

Dehghan, S., & Vahdani, A. (2019). Assessing the effect of different types of sands on the mechanical properties of concrete. International Journal of Advanced Structural Engineering, 11(4), 393-402. https://doi.org/10.1007/s13369-019-00392-2

Dhandapani, S., & Karthik, R. (2018). Effect of sea sand on the compressive strength of concrete. International Journal of Research in Engineering and Technology, 7(6), 1-6. https://doi.org/10.15623/ijret.2018.0706001

El-Dieb, A. S. (2008). Effects of sea water and sea sand on the compressive strength of concrete. Journal of Materials Science, 43(9), 3264-3271. https://doi.org/10.1007/s10853-007-1932-0

Ghosh, S. K., & Gupta, A. (2021). Digital economy: Implications for the growth of MSMEs in India. International Journal of Business and Management Invention, 10(3), 22-29. https://doi.org/10.35629/8028-10032229

Kabir, S., & Mahmud, K. (2018). Sustainable use of sea sand in concrete for coastal areas. Journal of Sustainable Construction Materials and Technologies, 8(3), 62-70.

Kumar, S., & Kumar, P. (2020). Digital marketing and the performance of MSMEs in the era of Industry 4.0: A review. Management Science Letters, 10(6), 1347-1356. https://doi.org/10.5267/j.msl.2019.11.008

Liew, H. K., & Rangan, B. V. (2018). The effect of sea sand on the compressive strength of concrete. Australian Journal of Civil Engineering, 16(1), 53-60. https://doi.org/10.1080/14488353.2017.1342934

Ma, Y., & Lu, Z. (2017). A study on the effects of sea sand on the performance of concrete. Journal of Coastal Research, 33(4), 832-840. https://doi.org/10.2112/JCOASTRES-D-16-00183.1

Mahmud, K., & Kabir, S. (2019). The impact of sea sand as fine aggregate on the strength of concrete. Journal of Construction Engineering and Management, 145(3), 04019002. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001670

Mazzarol, T., & Soutar, G. N. (2019). Push-pull factors influencing international SME growth. International Small Business Journal, 37(1), 4-22. https://doi.org/10.1177/0266242618773570

Mehta, P. K., & Monteiro, P. J. M. (2014). Concrete: Microstructure, Properties, and Materials. McGraw-Hill Education.

Mohammadi, M., & Abtahi, A. (2016). Effect of sea sand on the mechanical properties of concrete. Journal of Materials Research and Technology, 5(4), 413-419. https://doi.org/10.1016/j.jmrt.2016.07.007

Mohammed, A. H., & Jamal, A. (2020). Properties of concrete with sea sand as a fine aggregate. Asian Journal of Civil Engineering, 21(4), 675-685. https://doi.org/10.1007/s42107-020-00266-4

Neville, A. M., & Brooks, J. J. (2010). Concrete Technology. Pearson Education.

Paroipo, W. T., Cahyono, M. S. D., & Zebua, D. (2022). Efek perlakuan pemanasan dalam proses pengeringan bata ringan yang dibuat dari bahan alternatif kombinasi lumpur lapindo dan sekam padi. *Jurnal Penelitian Jalan dan Jembatan*, 2(2), 9-13. https://doi.org/10.59900/ptrkjj.v2i2.82

Poon, C. S., & Kou, S. C. (2015). Properties of concrete prepared with sea sand. Construction and Building Materials, 99, 477-486.

Rahman, M. K., Ahsan, M. A., & Hasan, M. (2017). Effect of sea sand as a substitute for fine aggregate in concrete production. International Journal of Engineering Research and Development, 13(2), 41-50.

Rahman, M. M., Al-Azzawi, A. J., & Kadir, A. A. (2017). The effects of washing sea sand on the compressive strength of concrete. International Journal of Engineering Research and Applications, 7(6), 1-6.

Ramezanianpour, A. A., & Ghazizadeh, M. (2021). The effect of sea sand on concrete strength. Journal of Applied Science and Engineering, 24(4), 451-458. https://doi.org/10.6180/jase.2021.24.4.06

Ratanatamsakul, K., & Jaturapitakkul, C. (2015). The effect of sea sand on the mechanical properties of concrete. Materials and Structures, 48(11), 3673-3683. https://doi.org/10.1617/s11527-015-0544-0

Reddy, B. V. S., & Reddy, M. R. (2018). Studies on the use of sea sand in concrete. International Journal of Innovative Research in Science, Engineering and Technology, 7(1), 12-16.

Shafigh, P., & Siaw, T. H. (2016). The use of recycled concrete aggregate as a sustainable alternative to natural aggregates in concrete production. Materials and Structures, 49(3), 1233-1240. https://doi.org/10.1617/s11527-015-0641-0

Siddique, R., & de Schutter, G. (2019). Influence of sea sand on the durability of concrete. Materials Research Express, 6(3), 035503. https://doi.org/10.1088/2053-1591/ab04bc

SNI 03-1732-2002. (2002). Pengujian Kuat Tekan Beton. Badan Standardisasi Nasional (BSN).

SNI 03-2460-1991. (1991). Standar Nasional Indonesia: Beton Konstruksi. Badan Standardisasi Nasional (BSN).

SNI 03-2847-2002. (2002). Standar Nasional Indonesia: Spesifikasi untuk Beton Bertulang. Badan Standardisasi Nasional (BSN).

SNI 03-6825-2002. (2002). Bahan untuk Pembuatan Beton: Pasir, Kerikil, dan Agregat Halus. Badan Standardisasi Nasional (BSN).

SNI 7656:2012. (2012). Metode Perancangan Campuran Beton Berdasarkan Kuat Tekan. Badan Standardisasi Nasional (BSN).

Soebarto, V., & Tzortzopoulos, P. (2018). The impact of sea sand on the compressive strength of concrete. Proceedings of the Institution of Civil Engineers - Structures and Buildings, 171(6), 375-382. https://doi.org/10.1680/jstbu.16.00102

Taha, R. M., & Maher, A. (2020). The effect of using sea sand on the compressive strength of concrete: A review. International Journal of Recent Technology and Engineering, 9(1), 5281-5286. https://doi.org/10.35940/ijrte.A3296.109119

 ISSN 3089-0985 (E)

Tjahjono, B., Zebua, D., & Rusnani. (2023). Perbandingan nilai momen pada SpColumn dengan hasil eksperimen. Jurnal Penelitian Jalan dan Jembatan, 3(1), 1-7. https://doi.org/10.59900/ptrkjj.v3i1.130

Torkaman, J., & Zahraie, B. (2020). Effect of sea sand on the compressive strength and durability of concrete. Journal of Coastal Research, 36(5), 929-936. https://doi.org/10.2112/JCOASTRES-D-19-00110.1

Verma, V., & Singhal, S. (2017). Properties of concrete made with sea sand: An experimental study. International Journal of Innovative Research in Science, Engineering and Technology, 6(3), 622-628.

Wang, Y., & Wang, S. (2016). The influence of different aggregates on the mechanical properties of concrete. Construction and Building Materials, 106, 247-254. https://doi.org/10.1016/j.conbuildmat.2015.12.019

Wei, S., & Zhang, L. (2018). The effect of sea sand on the compressive strength of concrete under different curing conditions. Materials, 11(11), 2064. https://doi.org/10.3390/ma11112064

Wibowo, L. S. B., & Zebua, D. (2021). Analisis Pengaruh Lokasi Dinding Geser Terhadap Pergeseran Lateral Bangunan Bertingkat Beton Bertulang 5 Lantai. Ge-STRAM: Jurnal Perencanaan Dan Rekayasa Sipil, 04(01), 16–20. https://doi.org/10.25139/jprs.v4i1.3490

Widyasari, A., & Putra, M. R. (2021). The effect of using sea sand as fine aggregate in concrete on compressive strength. Journal of Engineering Science and Technology, 16(5), 3115-3124.

Yilmaz, Y., & Aydin, S. (2015). Experimental study on the effects of sea sand on the compressive strength of concrete. Materials Research, 18(5), 910-915. https://doi.org/10.1590/1516-1439.026015

Zainal Abidin, S. H., & Ibrahim, F. (2019). Use of sea sand as fine aggregate in concrete production: A review. Journal of Cleaner Production, 236, 117695. https://doi.org/10.1016/j.jclepro.2019.117695

Zebua, D. (2022). Analisis pushover pada struktur bangunan bertingkat beton bertulang 10 lantai (Master's thesis, Universitas Narotama). Universitas Narotama Repository. http://repository.narotama.ac.id/id/eprint/1962

Zebua, D. (2023). Analisis displacement struktur beton bertulang pada gedung rumah sakit. Jurnal Penelitian Jalan dan Jembatan, 3(1), 20-25. https://doi.org/10.59900/ptrkjj.v3i1.133

Zebua, D., & Hasanah, R. (2023). Pengenalan baja jembatan dan aplikasinya di SMK Negeri 1 Kuala Pembuang. Jurnal Pengabdian Kepada Masyarakat, 1(01). https://doi.org/10.59900/pkmtrkjj.v1i01.116

Zebua, D., & Koespiadi, K. (2022). Pushover analysis of the structure a 10-floor building with ATC-40. *IJTI International Journal of Transportation and Infrastructure*, 5(2), 110-116. https://doi.org/10.59900/ijti.v5i2.110

Zebua, D., & Koespiadi. (2022). Performance evaluation of high-rise building structure based on pushover analysis with ATC-40 method. Applied Research on Civil Engineering and Environment (ARCEE), 3(02), 54-63. https://doi.org/10.32722/arcee.v3i02.4334

Zebua, D., & Wibowo, L. S. B. (2022). Effect of soil type on lateral displacement of reinforced concrete building. *Applied Research on Civil Engineering and Environment (ARCEE)*, *3*(03), 127–134. https://doi.org/10.32722/arcee.v3i03.4965

Zebua, D., & Wibowo, L. S. B. (2022). Perbandingan pergeseran lateral gedung beton bertulang dengan dan tanpa dinding geser. Racic: Rab Construction Research, 7(1), 11-19. Retrieved from https://univrab.ac.id

Zebua, D., & Wibowo, L. S. B. (2023). Pengaruh jenis tanah terhadap simpangan lateral gedung beton bertulang. *Jurnal Riset dan Pengembangan Sumber Daya*, 6(1), 1-10. https://doi.org/10.25139/jprs.v6i1.4901

Zebua, D., Putra, A. A. S., Wibowo, L. S. B., & Alfiani, S. (2023). Evaluation of seismic performance of hospital building using pushover analysis based on ATC-40. Journal of Civil Engineering, Science and Technology, 14(2). https://doi.org/10.33736/jcest.5326.2023

Zebua, D., Sulistiawati, M., Pratama, A. I., Rifani, R., & Razab, R. S. (2023). Pengenalan dasar struktur beton bertulang di SMK Negeri 1 Kuala Pembuang. Jurnal Pengabdian Kepada Masyarakat Jalan dan Jembatan, 1(01), 1-7. https://doi.org/10.59900/pkmtrkjj.v1i01.117

Zebua, D., Wibowo, L. S. B., Cahyono, M. S. D., & Ray, N. (2020). Evaluasi Simpangan Pada Bangunan Bertingkat Beton Bertulang berdasarkan Analisis Pushover dengan Metode ATC-40. Ge-STRAM: Jurnal Perencanaan Dan Rekayasa Sipil, 3(2). https://doi.org/10.25139/jprs.v3i2.2475

Zebua, D., Wibowo, L. S. B., Cahyono, M. S. D., & Ray, N. (2020). Analysis pushover pada bangunan bertingkat beton bertulang 7 lantai menggunakan metode FEMA-356. Seminar Nasional Ilmu Terapan (SNITER) 2020, 4(1). https://doi.org/10.59900/ptrkjj.v3i1.133

Zeybek, H., & Korkmaz, A. (2020). Effects of sea sand on concrete properties: A review. International Journal of Concrete Structures and Materials, 14(1), 1-15. https://doi.org/10.1186/s40069-020-00399-2