International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 13 Issue 8 ǁ August 2025 ǁ PP.208-218

The Impact of Morowali Sea Sand as A Partial Substitute of Fine Aggregate on The Concrete Compressive Strength

Egi Hendrawan [1], Fatmawati Amir [2]*, Gidion Turuallo [2]
[1,2]Master of Civil Engineering Program, Faculty of Engineering, Tadulako University, Palu, Indonesia
Coressponding Author: fatmawati@untad.ac.id

Abstract: *This study examines the effect of sea sand as a partial substitute of fine aggregate on the concrete compressive strenght. An experimental quantitative research method with ANOVA was used, with substitution rates of 25%,50% and 75% using washed and unwashed sea sand. The test specimens were concrete cylinders with diameter of 150 mm and 300 mm of high, which were cured for 28 days before testing. The results showed that fully washed sea sand could substitue fine aggregate without significantly reducing the quality of the concrete. The highest performance was achieved with the use of 75% washed sand, resulting in a compressive strength of 25.46 MPa. These test results indicate that washed sea sand was propered and sustainable alternative to replace natural fine aggregate in concrete production.*
Keywords: *Sea Sand, Compressive Strength, Substitute, Cylindrical Specimen*

Date of Submission: 14-08-2025 Date of acceptance: 28-08-2025

I. INTRODUCTION

Indonesia as an archipelagic country with natural resources, including extensive sea sand deposits in coastal and island regions. In remote areas or small islands, the availability of conventional fine aggregates such as river sand is often limited. Hence, the sea sand could be a potential alternative as a partial substitute for fine aggregate due to it easy to access and lower transportation costs. However, its use in concrete production remains controversial because sea sand typically contains high levels of chlorides and sulfates, which can corrode steel reinforcement, reduce concrete durability, and reduce structural performance if not properly processed.

Previous research has shown that leaching sea sand can significantly reduce salt content and improve its suitability as a construction material. However, its effect on the mechanical properties of concrete, particularly compressive and flexural strength, remains an important area of study—especially in determining the optimal substitution percentage to maintain or improve concrete performance.

The growing demand for infrastructure development in coastal and island areas highlights the need to utilize local materials to reduce project costs and support sustainable construction practices. By partially replacing fine aggregate with properly washed sea sand, it is possible to achieve economic and environmental benefits while addressing material shortages in remote areas.

Therefore, this study aims to: (1) analyze the effect of sea sand substitution on the compressive strength and flexural strength of concrete, and (2) determine the optimal substitution percentage for maximum performance. The results of this study are expected to provide technical recommendations for the safe and efficient use of sea sand as a fine aggregate in concrete production, thereby contributing to the development of sustainable infrastructure in coastal and islands areas.

1.1 Literature Review

Dumyati & Manalu (2015) examined Sampur sea sand with various treatments, finding that washing effectively reduced salt and increased compressive strength to 22.14 MPa, although still below of normal concrete (28.68 MPa).

Zulkarnain & Alqory (2024) reported a decrease of the split tensile strength of concrete as the proportion of the sea sand was increased, but the addition of the Sikacim additive was able to increase the tensile strength, for example in a mixture of 30% sea sand from 2.56 MPa to 3.01 MPa.

Ruslan Ramang et al. (2014) showed that Alor Kecil sea sand, both natural and washed, met SNI standards, with washing increasing the compressive strength (24.53 MPa) and splitting tensile strength (3.11 MPa), although it remained lower than sea sand from other location in Nias island (Takari sand).\

Lestari et al. (2024) identified high levels of heavy metals Ni and Fe in coastal sediments of Fatufia, Morowali, which exceeded the quality standards due to mining activities. It potentially pollutes the environment and affects health. On the other hand, Ni and Fe contents in this sea sand, make it can be used as a potential alternative as a partial substitute of fine aggregate for construction.

1.1.1 Concrete

According to (SNI 2847 2013), the definition of concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additional materials that form a solid mass.

1.1.2 Concrete Components

Concrete is composed of a mixture of Portland cement, fine aggregate (sand), coarse aggregate (gravel), water, and air. The fine aggregate is usually natural or processed sand, while the coarse aggregate is made from natural stone or crushed stone. The material composition must be precisely calculated to ensure the mixture is easy to work with and achieves the desired compressive strength after 28 days of curing.

1. Aggregate Material

SNI 03-287-2013 defines aggregate as a granular material, such as sand, gravel, crushed stone, and blast furnace slag, used with a bonding medium to produce concrete or hydraulic cement mortar. Concrete aggregates can generally be divided into coarse aggregate and fine aggregate.

A. Coarse Aggregate

According to SNI 03-2834-2000, coarse aggregate is natural sand as a result of the natural disintegration of stone or in the form of crushed stone obtained from the stone crushing industry and has a grain size of between 5 mm – 40 mm.

B. Fine Aggregate

According to SNI 03-2834-2000, fine aggregate is natural sand resulting from the natural disintegration of stone or sand produced by the stone crushing industry and has a largest grain size of 5.0 mm.

2. Cement

Cement is a fine material that acts as an aggregate binder. Cement's raw materials contain oxides such as lime, silica, alumina, and iron oxide. Cement acts as a binder, binding coarse and fine aggregates into a solid mass through a hydration process.

3. Water

Water is necessary in concrete production because it reacts with the cement, which binds the aggregate. Water also affects the compressive strength of the concrete itself, as excess water will reduce its strength.

1.1.3 Sea Sand

Sea sand is a fine aggregate with fine, rounded grains due to friction, but its quality is low because it contains salts that can cause moisture, swelling, and corrosion of reinforcing steel. Its use as a building material is only acceptable if it meets standards, especially regarding the salt content which according to British Code CP 110:1972 is limited to a maximum of 1% of the cement weight (0.1% for prestressed concrete or alumina cement). Sea sand is divided into those affected by tides and those not affected by tides, with the salt content being lower in the latter, although the chemical and waste content is higher. To be used in structural concrete, sea sand needs to be stabilized to reduce the salt content and have coarse grains with varying gradations within the specified limits.

1.1.4 Mixture Proportion Calculation

The calculation of concrete mixture proportions in this study refers to SNI 03-2843:2000, with the determination of a minimum average compressive strength of f'c + 12 MPa if standard deviation data is not available. The water-cement ratio (FAS) is determined based on the empirical relationship between compressive strength and FAS, with a maximum limit according to environmental conditions. The minimum cement amount, slump value, and maximum aggregate grain size are adjusted to ensure workability and concrete quality. Free water requirements are calculated from reference tables and adjusted for different aggregate mixtures. Aggregate specific gravity is used from test results or standard values, then all mixture components are calculated in kg/m^3. Proportion corrections are made if the aggregate is not in a surface-dry saturated condition to adjust the actual water content.

1.1.5 Concrete Compressive Strength

SNI 03-1974-199 defines concrete compressive strength as the magnitude of the surface load that causes a concrete test object to collapse when loaded with a certain compressive force. The compressive strength of each test object is determined by the maximum compressive stress (f'c) achieved by the test object after 28 days due to compressive loading during the test. The formula for obtaining the highest compressive stress value (f'c) based on laboratory experiments is as follows:

$$88f'c = \frac{P}{A} \quad (1)$$

Where:
f'c = concrete compressive strength (kg/cm2)
P = maximum load (kg)
A = cross-sectional area (cm2)

1.1.6 Analisis of Variance (ANOVA)

ANOVA is a calculation technique that allows quantitatively estimating the contribution of each factor to all response measurements. Analysis of variance used in parameter design is useful for identifying factor contributions, thereby determining the accuracy of model estimates. ANOVA is used as a statistical method to interpret experimental data. Meanwhile, the type of measurement data can be analyzed using Analysis of Variance for Variable Data (Kurniawan, 2018). ANOVA used in experimental results is generally a two-way ANOVA analysis. Two-way ANOVA is experimental data consisting of two or more factors and two or more levels.

II. MATERIALS AND RESEARCH METHOD

This study uses an experimental quantitative study to examine the effect of partial substitution of fine aggregate with sea sand on the compressive strength of concrete. The two main variables studied are:
1. Sea sand substitution percentage: 25%, 50%, and 75%.
2. Treatment conditions: washed and unwashed sea sand.
All specimens were cured for 28 days before testing, in accordance with SNI standards.

2.1 Materials

Tonasa brand Portland cement is used as a binder material as shown in Figure 1. Water should be clean, drinkable water and meets the requirements for concrete mix design. Coarse Aggregate proceed as crushed stone with gradation according to SNI 03-2834-2000 (Figure 2).

Figure 1: Portland cement

Figure 2: Coarse Aggregate

Fine Aggregate were originated from River sand of Palu and sea sand from Matano Village, Morowali, as can be seen on Figure 3.

a: River sand

b: Sea sand

Figure 3. Fine Aggregate

2.2 Sea sand Treatment

This stage includes the preparation and treatment of sea sand before it is used as fine aggregate in the concrete mixture. Sea sand was taken from Matano Village, Bungku Tengah District, Morowali Regency, Central Sulawesi, Indonesia (Latitude: 2°32'7.40" S, Longitude: 121°58'7.08" E) (Figure 4). Sieve analysis was carried out according to SNI 03-2834-2000 to determine the grain size distribution of river and sea sand.

Figure 4: Sea sand site

2.2.1 Washing Procedure

The sand was washed three times using fresh water to reduce the chloride and sulfate content, with the target of meeting the limits set in British Code CP 110:1972 (NaCl content ≤ 1% for conventional concrete, ≤ 0.1% for prestressed concrete) as shown on Figure 5.

Figure 5: Washing Process

2.2.2 Physical and Chemical Testing

This stage was conducted after the washing prosedure, the sand is tested for:
a) Organic Waste (SNI 2816:2016)
b) Specific Gravity and Water Absorption (SNI 1970:2016)
c) Chloride Content (SNI 06-6989.24-2005)
The sand is air-dried in a shady place and stored in a closed container before use for concrete mix design, after the physical and chemical testing.

2.2.3 Mixed Design

The concrete mix design follows SNI 03-2847-2013, with compressive strength of 17.5 MPa at 28 days. The mix proportions are adjusted based on the sea sand substitution percentage and moisture content (SSD). Slump tests are conducted to ensure workability is within the 60–180 mm range.

2.2.4 Specimens Preparation

Compressive Strength specimens were cylindrical specimens (150 mm × 300 mm) and casting for each variation, depicted on Figure 6.

Figure 6: Concrete cylindrical cast

2.2.5 Compressive Strength

Compressive Strength was conducted in accordance to SNI 03-1974-2011 using a compression testing machine (Figure 7). The maximum load at failure is recorded and converted to compressive strength of MPa (Mega Pascal).

Figure 7: Compression testing machine

2.3 Data analysis

The experimental results were analyzed using descriptive statistics and two-way Analysis of Variance (ANOVA) to determine the effect of substitution percentage and washing treatment on the mechanical properties of concrete.

III. RESULTS AND DISCUSSION

3.1 The Physical Properties of Materials

The physical properties results data of materials can be seen on Table 1 to Table 3, :

Table 1. The Physical Properties of Coarse Aggregate

Type of Examination	Values obtained	Boundary Conditions
Gradation	6,72	Fine Modulus = 6,30 -6,75 (D = 20 mm)
SSD type weight	2,77	≥ 2.3
Absorption (%)	1,33	≤ 2%
Sludge Rate (%)	0,06	≤ 1%
Aggregate wear (%)	14,04	Max. 40%

Table 2. The Physical Properties of River Sand

Type of Examination	Values obtained	Boundary Conditions
Gradation	2,35	Fine Modulus = 2.11 - 3.37 (Zona 2)
SSD type weight	2,54	≥ 2.3
Absorption (%)	1,58	≤ 2%
Sludge Rate (%)	0,31	≤ 1%
Organic waste	No. 1	-

Table 3. The Physical Properties of Sea Sand

Type of Examination	Values obtained	Boundary Conditions
Gradation	2,67	Fine Modulus = 2.11 - 3.37 (Zona 2)
SSD type weight	2,51	≥ 2.3
Absorption (%)	3,64	≤ 2%
Sludge Rate (%)	0,45	≤ 1%
Organic waste	No. 3	-
Sand Salt Rate is not washed	0,086	≤ 1%
Salt Rate Sand washed	0,032	≤ 1%

3.2 Concrete Mix Design

Based on the concrete mix design according to SNI 03-2834-2000 (Normal Concrete Manufacturing Procedures), the proportions of the mixed materials are as follows:

Table 4. Concrete Mix Design

Material Type	Volume of Concrete Material (kg)			
	(Normal Concrete, 0% of sea sand)	(25% of sea sand)	(50% of sea sand)	(75% of sea sand)
Coarse Aggregate	32.002	32.002	32.002	32.002
River sand	22.239	16.679	11.119	5.560
Sea sand	0.000	5.560	11.119	16.679
Cement	12.498	12.498	12.498	12.498
Water	6.249	6.249	6.249	6.249

3.3 Slump Test

Based on the results of the slump test for one mixing, which was used in the mix designs of 5 cylinders and the slump value for each mixing is shown in the following table and figures:

Table 5. Slump Test Value of Cylindrical Concrete

Types of Concrete Samples	Slump (mm)	Information
Normal concrete	100	-
25% of sea sand substitution	80	Unwashed sea sand
	85	Washed Sea sand
50% of sea sand substitution	60	Unwashed sea sand
	80	Washed Sea sand
75% of sea sand substitution	55	Unwashed sea sand
	60	Washed Sea sand

Figure 8. Slump test of normal concrete, none of sea sand

Figure 9. Slump test of concrete (25% of unwashed sea sand substitution)

Figure 10. Slump test of concrete (25% of washed sea sand substitution)

Figure 11. Slump test of concrete (50% of unwashed sea sand substitution)

Figure 12. Slump test of concrete (50% of washed sea sand substitution)

Figure 13. Slump test of concrete (75% of unwashed sea sand substitution)

Figure 14. Slump test of concrete (75% of washed sea sand substitution)

Based on the previous table and figures, it can be seen that excessive amounts of sea sand can reduce the slump value of the fresh concrete. This indicates that the more sea sand added to the concrete mixture, the concrete become has lower workability both for washed and unwashed sea sand. Despite of the concrete mixtures contain by unwashed sea sand have lower slump value than washed sea sand.

3.4 Analysis of Concrete Compressive Strength Results

Concrete compressive strength was conducted at 28 days of concrete age. First step was began with measuring the weight of the test specimens, flattening the surface of all the test specimens with sulfur capping, and then conducting a compression test by a hydraulic compression machine until the maximum load was reached. The failure mode of compression strength results are presented in Figures 15 to 21.

Figure 15. Failure mode of normal concrete

Figure 16: Failure mode of substitute 25% unwashed sea sand

Figure 17. Failure mode of substitute 25% washed sea sand

Figure 18. Failure mode of substitute 50% unwashed sea sand

Figure 19. Failure mode of substitute 50% washed sea sand

Figure 20: Failure mode of substitute 75% unwashed sea sand

Figure 21. Failure mode of substitute 75% washed sea sand

As we can see from Figure 15-21, all washed specimen have smoothen and little amount of crack, they were indicated that washed sea sand can reduce the mineral of salt and give a good binding of cement paste and agregates. After all testing has been successfully completed, the next stage is data processing and can be describe below.

3.4.1 Concrete Compressive Strength versus Sea Sand Percentage

The concrete compressive strength values for each test are tabulated in the following table:

Table 6. Concrete Compressive Strength

No	Types of Concrete Specimen	Concrete Compressive Strength (MPa)	Sand Description
1	Normal concrete	17.83	River sand
2	Substitution of 25% sea sand	18.11	Unwashed sea sand
		21.39	Washed Sea sand
3	50% sea sand substitution	20.88	Unwashed sea sand
		22.64	Washed Sea sand
4	Substitution of 75% sea sand	21.00	Unwashed sea sand
		25.46	Washed Sea sand

From the table above, a comparative graph of the concrete compressive strength sample types was obtained as follows:

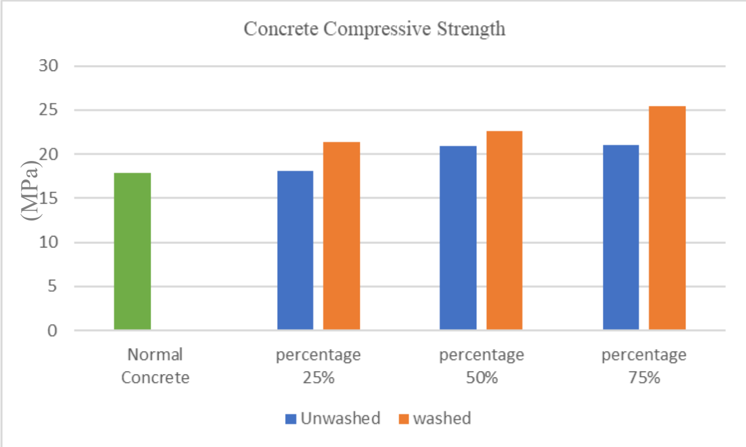

Figure 22: Concrete Compressive Strength

Figure 22 shows that, the compressive strength of concrete at 28 days increases with the percentage of sea sand in the concrete mixture was risen. This increase occurs in both washed and unwashed sea sand, although the highest compressive strength is achieved in the washed sea sand concrete mixture. This is consistent with the theory outlined previously, which states that the process of washing sea sand can increase the compressive strength of concrete.

3.4.2 Comparison of strength between normal concrete and concrete with sea sand substitution

Based on Figure 22, the strength of the normal concrete sample used as a reference shows a compressive strength test result of 17.83 MPa, which has met the standard compressive strength design of 17.50 MPa. All concrete samples are within the specified target range. In addition, the test results also show that increasing the percentage of sea sand in the concrete mixture tends to increase the compressive strength of the concrete.

3.4.3 Optimum composition of sea sand substitution for concrete compressive strength

Based on the experimental results, the optimum composition of sea sand addition was obtained at a content of 75%. This is based on previous conclusions showing that increasing the proportion of sea sand in the concrete mixture is directly proportional to the rise in concrete compressive strength at the age of 28 days. Therefore, washed sea sand with a composition of 75% was chosen as a substitute for conventional sand in the manufacture of concrete mixtures.

3.4.4 Validation of factors influencing concrete compressive strength using ANOVA

After manual calculations were carried out, these results were re-validated using the Minitab application to determine the largest contribution of the sand washing factor with the percentage of substitution of additional sea sand, which can be seen in the following image:

Table 7. Results of Analysis of Variance (ANOVA)

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
aggregate state	1	15.073	51.81%	15.81	15.0734	16.34	0.056
percentage	3	12.175	41.85%	12.175	6.0873	6.60	0.132
Error	3	1.845	6.34%	1.845	0.9226	-	-
Total	7	29.093	100.00%	-	-	-	-

Based on Table 7, The results of the analysis show that sea sand washing factors (aggregate state) has the most dominant influence on concrete performance with a contribution of 51.81% and a P-value of 0.056 which is close to significant, so the condition of the sand before use greatly determines the quality of the mixture. Meanwhile, percentage of fine aggregate substitution contributed 41.85% but with a P-value of 0.132, it is indacate that the effect was not statistically significant. Thus, it can be concluded that sea sand washing plays a greater role in improving concrete quality than variations in the percentage of fine aggregate substitution.

III. CONCLUSION

Based on the research results, the following conclusions can be drawn: The use of washed sea sand as a substitute for fine aggregate has not significantly reduced the quality of concrete. The highest compressive strength, 25.46 MPa, was achieved in a mixture containing 75% washed sea sand. Full substitution (75%) of sea sand resulted in the best mechanical performance, provided the sand was thoroughly washed to remove salt and impurities. This indicates that sea sand can be fully used as a fine aggregate in concrete.

REFERENCES

[1]. Dumyati, A., & Manalu, F. D. (2015). Analysis of the use of Sampur sea sand as .Fropil Journal, vol 3(1), 119-127.
[2]. Hizrian. (2017). Understanding aggregates and their classification. Retrieved from gurusipil.com: https://hizrian.medium.com/pengertian-agregat-dan-klasifikasinya
[3]. Kurniawan, r. (2018). Determination of the optimal factor level combination for terrazzo chairs based on compressive strength tests using the Taguchi method.Malang: Brawijaya University.
[4]. Lestari, W. D., Umar, R. S., Priosambodo, D. (2024). Analysis of Nickel and Iron Content in Coastal Water Sediments of Fatufia Village, Bahodopi District, Morowali Regency, Central Sulawesi.Makassar Journal of Biology (Biome), vol 9 number 1, 1-13.
[5]. Mulyono, t. (2015).Concrete technology: from theory to practice.Jakarta: educational development institute-unj.
[6]. Razak, r. (2023).The relationship between load and deflection on concrete beams.Makassar: Bosowa University.
[7]. Ramang, R., Sina, T. A.D., & Irpan, M. (2014). Technical feasibility study of the use of Alor sea sand.Civil Engineering Journal vol. III, no. 2, 111-124.
[8]. SNI-03-2834-2000. (2000). Tata Cara Pembuatan Rencana Campuran Beton Normal. Badan Standardisasi Nasional (BSN).
[9]. SNI-1974-2011. (2011). Cara Uji Kuat Tekan Beton Dengan Benda Uji Silinder. Badan Standardisasi Nasional (BSN).
[10]. SNI-4431-2011. (2011). Cara Kuat Lentur Beton Normal Dengan Dua Dengan Dua Titik Pembebanan. Badan Standardisasi Nasional (BSN).
[11]. SNI-2847-2013. (2013). Persyaratan Beton Struktural Untuk Bangunan Gedung. Badan Standardisasi Nasional (BSN).
[12]. SNI-4154-2014. (2014). Metode Uji Kekuatan Lentur Beton. Badan Standardisasi Nasional (BSN).
[13]. SNI-2847-2019. (2019). Persyaratan Beton Struktural Untuk Bangunan Gedung Dan Penjelasan. Badan Standardisasi Nasional (BSN).
[14]. Tjokrodimuljo, k. (2009).Technology concrete.Yogyakarta: Civil and Environmental Engineering, Gadjah Mada University.
[15]. Zamilconsulting. (2021). Understanding Aggregates And Their Classification. Retrieved from zamilconsulting: https://zamilconsulting.com/pengertian-agregat-dan-klasifikasinya/
[16]. Zulkarnain, F & Alqory R. D. (2024). The Effect Of Using Sea Sand As A Mixture Of Fine Aggregate With .Civil Engineering Scientific Journal (Jimmats) vol. 03, no. 01, 038 – 043.