Utilization of Construction Concrete Waste as Aggregate Substitutes in Normal Concrete Production

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Abstract. The construction process frequently necessitates the demolition of existing structures, resulting in substantial construction waste. A significant portion of this waste comprises demolition debris, particularly from concrete building materials. This research aims to develop standard concrete by partially substituting conventional coarse and fine aggregates with concrete waste materials. The substitutions involved replacing 25% and 50% of sand and gravel, respectively, by weight, using a K300 concrete mix design. Adopting the SNI 03-2834-2000 method, the mix design for 1 cubic meter of concrete comprised cement (528 kg), sand (776.16 kg), gravel (807.04 kg), and water (205 kg). The results indicated an average sample weight reduction, with the first sample at 12.91 kg, the second at 12.79 kg, and the third at 12.77 kg. This weight decrease suggests that using waste as a partial aggregate substitute impacts concrete density. Compressive strength tests revealed a reduction of 5.98% in the concrete containing a 25% waste mixture, with average compressive strength declining from 307.22 kg/cm² to 288.94 kg/cm². A more pronounced reduction occurred in the 50% waste mixture, where compressive strength decreased by 15.70% (from 307.22 kg/cm² to 259.06 kg/cm²). This trend aligns with the understanding that higher waste content correlates with greater mechanical strength reduction, likely due to the differing physical properties of waste materials, such as lower density, which impact overall concrete performance, particularly in compressive strength.

Keywords: Recycled concrete, construction waste, aggregate substitution, compressive strength.

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INTRODUCTION

Infrastructure development in Indonesia is advancing rapidly, particularly in the construction of buildings, roads, and other facilities. This growth has resulted in a heightened demand for construction materials. Concurrently, renovations and demolitions of older buildings are frequently undertaken to meet evolving functional and design needs. These processes, however, produce substantial construction waste, predominantly concrete waste, which requires effective management to reduce environmental impact [1].

The construction sector generates various types of waste, with concrete waste comprising approximately 35,4% of the total waste generated [2]. This concrete waste has the potential for reuse in new concrete mixtures. Previous research has shown that substituting 60% of fine aggregate with concrete waste can increase concrete compressive strength by 14,89% [3].

However, not all studies indicate positive result, one of study found that replacing 25% of coarse aggregate with concrete waste led to a substantial reduction in compressive strength, by as much as 45.39% [4]. Another research shown that 3,52% decrease in compressive strength, which was attributed to sludge content exceeding the maximum allowable limit in aggregates derived from concrete waste [5].

Based on these findings, this research aims to explore the use of concrete waste as a substitute for both coarse and fine aggregates in the production of K-300 concrete. This study integrates approaches from previous research to optimize the incorporation of concrete waste in construction.

METHODS

This research employs an experimental approach to develop recycled concrete materials as a solution for reusing and recycling concrete construction waste into raw materials for producing new concrete. The research activities are structured in a research activity plan, as illustrated in **FIGURE 1.**

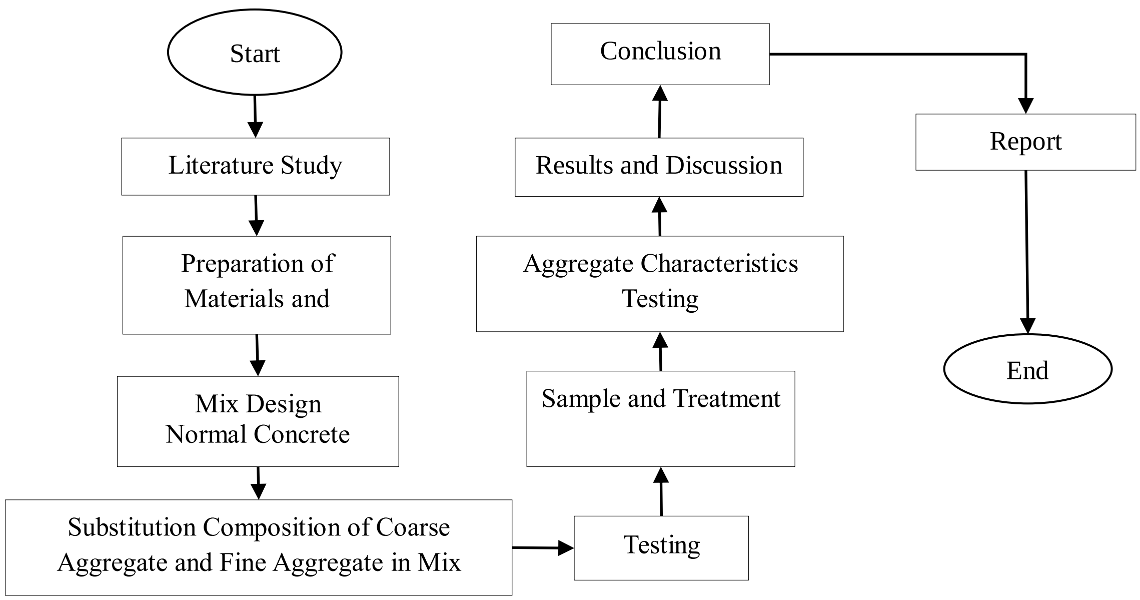

FIGURE 1. Flow Diagram

Materials

The materials utilized in this study are outlined below, in accordance with the Indonesian Standard (SNI 03-2834-2000) for normal concrete mix designs:

- **Cement**: Portland cement Type I, recognized for its versatility and compatibility with various types of aggregates.
- **Fine Aggregate**: A combination of natural river sand and crushed recycled concrete waste, sieved to achieve a particle size distribution that matches standard sand (0.075 mm to 4.75 mm).
- **Coarse Aggregate**: A mixture of natural crushed stone and recycled concrete waste, with a maximum particle size of 20 mm, adhering to the gradation requirements for coarse aggregates in concrete mixes..
- **Water**: Clean, potable water that complies with SNI specifications for concrete production.

MIX DESIGN

The control mix, which contains no recycled aggregate, was designed to achieve a compressive strength of 300 kg/cm² after 28 days. In addition to this baseline, two experimental groups were created, with 25% and 50% of both fine and coarse aggregates replaced by recycled concrete waste. The specific proportions used in these mixes are detailed in Table 1. This approach follows the guidelines set out in SNI 03-2834-2000 and includes necessary adjustments for specific gravity due to the recycled aggregates' lower density and higher water absorption properties.

TABLE 1. Mix Proportions for 1 m³ Concrete

Mix Type	Cement (kg/m³)	Water (kg/m³)	Natural Sand (kg/m³)	Recycled Fine Aggregate (kg/m³)	Natural Coarse Aggregate (kg/m³)	Recycled Coarse Aggregate (kg/m³)
Control (0%)	528	205	776.16	-	807.04	-
25% Replacement	528	205	582.12	194.04	605.28	201,96
50% Replacement	528	205	388.08	388.08	403.92	403.92

SAMPLE MIXTURE

The test object samples use a cylindrical shape measuring 15 cm in diameter, 30 cm in height, so that the mixture portion of each sample is as presented in **TABLE 2.**

TABLE 2. Mix Proportions for Concrete Sample

Mix Type	Cement (kg)	Water (kg)	Natural Sand (kg)	Recycled Fine Aggregate (kg/m³)	Natural Coarse Aggregate (kg/m³)	Recycled Coarse Aggregate (kg/m³)
Control (0%)	2,8	1,09	4,11	-	4,28	-
25% Replacement	2,8	1,09	3,09	1,03	3,21	1,07
50% Replacement	2,8	1,09	2,06	2,06	2,14	2,14

TESTING PROCEDURE

Concrete cylinders with dimensions of 150 mm in diameter and 300 mm in height were prepared and cured in a water bath for 28 days. The following tests were conducted:

1. **Compressive Strength Test**: Samples were tested at 28 days using a hydraulic press in accordance with SNI 03-1974-1990. The compressive strength was measured by dividing the maximum load at failure by the cross-sectional area of the samples.
2. **Density Test**: The mass and volume of each sample were measured to calculate density, following the procedure outlined in ASTM C138 for fresh and hardened concrete.

RESULTS AND DISCUSSION

TEST RESULTS FOR SPECIFIC GRAVITY OF CONCRETE

The effect of replacing concrete waste on the specific gravity (density) of concrete is measured using the volumetric specific gravity test method based on SNI standards. The use of waste aggregate as a substitute for aggregate will affect the density of concrete, because waste aggregate is generally less dense than natural aggregate. Below is a table of concrete density measurement results under conditions of concrete construction waste substitution treatment

TABLE 3. Sample Weight and Specific Gravity

No	Waste Concrete Substitution	Average Weight (kg)	Volume (m^3)	Specific Gravity (kg/m³)	Percentage reduction (%)
1	0% Substitusi	12,91	0,005299	2436,424	0,00%
2	25% Substitusi	12,79	0,005299	2414,406	0,90%
3	50% Substitusi	12,77	0,005299	2410,631	1,06%

From the table above, the specific gravity of concrete decreases of 0.90% at 25% waste substitution and 1.06% at 50% substitution. This decreases cause by the nature of the waste aggregates, which have higher porosity and lower density compared to natural aggregates. These are consistent with previous studies that indicate concrete waste typically has a lower density due to its less compact structure when compared to traditional aggregates. [1]

Reducing the specific gravity of concrete with waste substitution was also discussed in research, another researcher found that using concrete waste as a coarse aggregate produces concrete with a lower density but with increased workability. Reducing the specific gravity of concrete using fine or coarse aggregate waste can also reduce the durable properties of concrete, especially in terms of resistance to water penetration [6].

Another study showns that a decrease in specific gravity in concrete with waste contributes to a decrease in compressive strength. However, the research results also show that with proper processing and the addition of admixtures such as fly ash or superplasticizer, the density of concrete can be increased again, thereby maintaining the desired mechanical strength [2].

TEST RESULTS FOR COMPRESSIVE STRENGTH OF CONCRETE WITH WASTE SUBSTITUTION

The results of measuring the compressive strength of concrete with various percentages of waste aggregate substitution were carried out by testing three groups of concrete samples: the first group without substitution, the second group with 25% substitution, and the third group with 50% waste concrete aggregate substitution. The results of concrete compressive strength tests are presented in **TABLE 4**, **TABLE 5** and **TABLE 6.**

TABLE 4. Compressive Strength of Concrete Aged 28 Days (0% Substitution)

No	Waste Concrete Substitution	Force (KN)	Force Conversion (kg)	Sample Surface Area (cm^2)	Compressive Strength of Concrete (Kg/cm^2)
1	Sampel 1	538,09	54870	176,6	310.70
2	Sampel 2	536.91	54750	176,6	310.02

3	Sampel 3	521.71	53200	176,6	301.25
Average					307,32

TABLE 5. Compressive Strength of Concrete Aged 28 Days (25% Substitution)

No	Waste Concrete Substitution	Force (KN)	Force Conversion (kg)	Sample Surface Area (cm^2)	Compressive Strength of Concrete (Kg/cm^2)
1	Sampel 1	500.92	51080	176,6	289.24
2	Sampel 2	514.85	52500	176,6	297.28
3	Sampel 3	485.43	49500	176,6	280.29
Average					288,94

TABLE 6. Compressive Strength of Concrete Aged 28 Days (50% Substitution)

No	Waste Concrete Substitution	Force (KN)	Force Conversion (kg)	Sample Surface Area (cm^2)	Compressive Strength of Concrete (Kg/cm^2)
1	Sampel 1	447.18	45600	176,6	258.21
2	Sampel 2	402.07	41000	176,6	232.16
3	Sampel 3	496.71	50650	176,	286.81
Average					259,06

From all the table above, show decrease in the compressive strength of concrete with an increase in the percentage of concrete waste substitution:

1. 0% Substitution that used as a standard, show the compressive strength of concrete reaches 30,.22 kg/cm².
2. 25% Substitution show that reduction in compressive strength of 5,98%, to 288,94 kg/cm², and
3. 50% Substitution show reduction in compressive strength is increasingly significant to 15,70%, with compressive strength decreasing to 259,06 kg/cm².

The reduction in compressive strength of concrete with waste substitution is consistent with the results of previous research, where construction waste has an effect on the mechanical characteristics of concrete, especially on coarse and fine aggregates.

one of the researcher show that substitution of concrete waste as fine aggregate is used in large quantities of coarse aggregate, such as in the case of 50%, the negative influence on compressive strength is more dominant because the physical nature of the waste is more porous than natural aggregate [3].

Another researcher discovered that substituting fine and coarse aggregates with concrete waste, based on the Fuller curve, led to a 3.52% reduction in compressive strength [7].

Based on these findings, it is recommended to limit the use of concrete waste as a substitute to 25% to ensure the concrete maintains performance levels close to construction standards. Substitutions of 50% or more are only advised for non-structural applications or when additional technologies, such as admixtures, are employed to restore compressive strength

CONCLUSIONS

from this research we know that the use of recycled concrete waste as a partial subtitution for natural aggregates in concrete mixtures to minimize the impact of concrete waste on the environment. From this research, 25% replacement causes a minimal decrease in compressive strength. However, the use of 50% concrete waste as a substitute for natural fine and coarse aggregates shows a significant decrease in compressive strength. therefore, the concrete products with the results of this study are only suitable for application to non-structural concrete. Future research should explore methods to improve the performance of recycled aggregates, such as incorporating additives or improving aggregate processing techniques.

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