

Utilization of Mortar Waste as Environmentally Friendly Construction Material Replacement to Support Sustainable Development Goals

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Abstract. Due to its numerous advantages, concrete has become the most utilized construction material globally. However, concrete production causes environmental issues due to the high demand at each batching plant. Yogyakarta's ready-mix concrete factory generates 60 m³ of waste mortar monthly without further processing. This research examined the mortar waste as a replacement component for other valued construction materials, such as repair mortar, structural components, and rigid pavement, to achieve Sustainable Development Goals (SDGs) No. 9 and 11. Several laboratory tests were conducted, encompassing grain size analysis, specific gravity, water absorption, mud content, and water content. The user survey aims to understand the perspective and acceptance of using mortar waste as a construction material. Due to the test parameters not exceeding the required threshold, the results unveiled that the mortar waste could be applied as aggregate replacement in construction materials from an environmental perspective. In addition, the survey results expressed positive responses from potential material users.

1 Introduction

Sustained investment in infrastructure and innovation are essential drivers of economic development. More than half of the world's population lives in urban areas. Therefore, mass transportation and renewable energy are critical, as well as the growth of new industries and information and communication technology. This topic is in line with SDGs No.9.

Technological advances are also vital in finding long-term solutions to economic and environmental challenges, such as creating jobs and promoting energy efficiency. Promoting sustainable industries and investing in scientific research and innovation are essential to sustainable development.

In infrastructure engineering, concrete is a popular building material due to its durability, flexibility, and low cost [1]–[5]. Due to the growing demand for concrete for buildings,

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entrepreneurs strive to make various types of concrete, such as concrete with high performance, compressive strength, environmental resistance, and seismic shock resistance [1], [4], [6]–[10]. Sustainable construction designs have become popular, and the utilization of waste material is well-developed nowadays [11]–[13].

The factories employ batching facilities to produce enormous concrete volumes to meet demand. They utilize the low-strength mortar during manufacturing to wet all equipment used to transport concrete. Subsequently, the mortar is no longer required and is discarded [14]. The remaining mortar deposit can dry and accumulate, resulting in a daily production of 12.5 m³. While routine use does not exist, large numbers and continuous manufacturing are issues that must be overcome. This phenomenon has triggered environmental issues such as pollution, increased dust in the air, and scarcity of vacant land [15]–[18]. Figure 1 displays the deposit of waste material.



Fig. 2. Material deposit around the batching plant area in the concrete factory

A feasibility test must be conducted before using the mortar waste to ensure substance safety due to the absence of studies about identical materials. Material properties were tested through laboratory tests, and the perspective of the targeted users in utilizing the new material was examined using a qualitative survey.

2 Methods

Two research methods were employed: laboratory tests including grain size distribution, specific gravity, mud content, water absorption, and water content test, and a qualitative survey. Before conducting several laboratory tests, the samples were prepared by removing material from the quarry, drying it, and grinding it. The grain size gradation test followed ASTM C136: 2012, specifying test methods for fine and coarse aggregate sieve analysis. The dried samples were prepared in the X-ray diffraction (XRD) and X-ray fluorescence (XRF) tests, each in powder that passed the No. 200 sieve in a minimum of 10 grams under the applicable standards. Subsequently, a user survey was performed to understand their perspective and acceptance of using the waste material as a construction material.

3 Results and Discussions

Material testing was conducted to determine the characteristics of the mortar waste to be used as a mixture for making new concrete. The test results impacted the acquisition of the proportion of new concrete constituent material in the mix design calculation. The mix design calculation determined the proportion of material used in the new concrete-making process. Material testing followed the regulations and procedures to obtain results under the criteria. Figure 2 exhibits the appearance of the waste material.

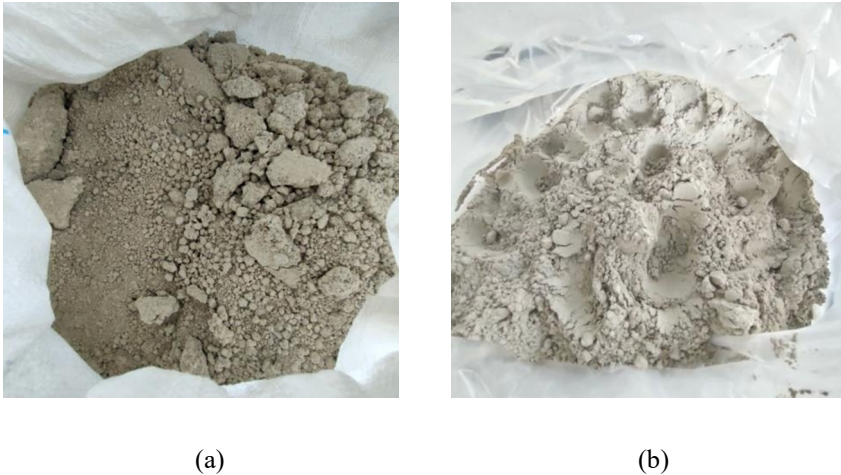


Fig. 2. The mortar waste (a) bulk waste material and (b) material passing sieve No. 200

3.1 Grain size distribution analysis

The grain size distribution test was conducted following ASTM C136: 2012 concerning fine and coarse aggregate sieve analysis test methods. The granule gradation test resulted in a fine grain modulus of 2.6382. With a range of 1.5-3.8, it met the required classification. The tested waste was also classified into the fine aggregate gradation table in SNI 03-2834-2000. Hence, the waste was categorized in the No. 2 gradation area, falling into the medium sand category. Figure 3 illustrates the grain size distribution graph.

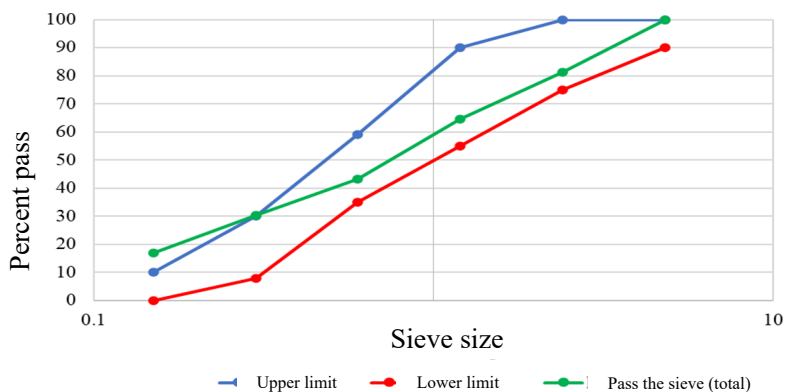


Fig. 3. Graphic of cumulative pass percentage

3.2 Specific gravity and water absorption

Specific gravity and water absorption tests followed procedures referring to SNI 1970:2008 concerning methods for testing specific gravity and water absorption of fine aggregate. Table 1 displays the test results: an average bulk specific gravity of 2.0114, an average apparent specific gravity of 2.4296, an average saturated surface dry (SSD) of 2.1830, and an average water absorption of fine aggregate (mortar waste) of 8.5%.

Table 1. Results of specific gravity and water absorption

Parameter	Trial 1	Trial 2	Average
Bulk specific gravity	1.9444	2.0784	2.0114
Saturated surface dry	2.1111	2.2549	2.1830
Apparent specific gravity	2.3333	2.5238	2.4286
Water absorption (%)	8.57	8.49	8.5

3.3 Water content

The water content test was carried out following SNI 1971: 2011 concerning testing the total aggregate moisture content by drying. Table 2 lists the water content of the waste, acquiring an average of 8.5%.

Table 2. Results of water content

Parameter	Trial 1	Trial 2	Unit
Dry waste weight in SSD (W1)	570	575	gram
Oven dry waste weight (W2)	525	530	gram
Water content	8.6	8.5	%
Average water content	8.53		%

3.4 Mud content

The mud content test was conducted based on SNI 03-4142-1996 concerning testing the amount of material in aggregate passing sieve No. 200 (0.075 mm). The test obtained an average grain content passing sieve No. 200 of 24.7%, as depicted in Table 3. The waste mud content did not meet the required standards—a maximum of 5%.

Table 3. Results of mud content

Parameter	Trial 1	Trial 2	Unit
Weight of furnace dry waste after washing	420	405	gram
Grain content passing sieve No. 200	23.64	25.69	gram
Average of grain content passing sieve No. 200	24.66		gram

3.5 Qualitative survey

The qualitative survey was conducted on 18 prospected users. The questions were about the possibility of mortar waste utilization as the new construction material replacement, such as fine aggregate or binder replacement. From the samples, 62.5% were interested in using the material. Figure 4 portrays the diagram of the survey results.

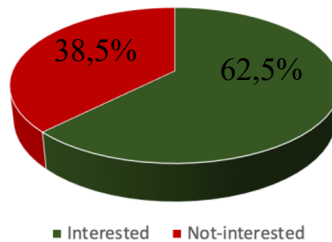


Fig. 4. Results of a qualitative survey of the prospective users

The laboratory tests, including grain size distribution, specific gravity, water absorption, and mud content, unveiled that the waste material was suitable for an acceptable aggregate replacement in the concrete mix. The qualitative survey results agreed with the laboratory tests.

4 CONCLUSIONS

A series of laboratory experiments and a qualitative survey revealed that using mortar waste as a substitute for aggregates in building materials was a viable option from an ecological standpoint. This conclusion was drawn because all test parameters remained within acceptable limits. Various building materials could reuse dry mortar waste, including paving blocks, patch repairs, bricks, light structures, and similar components. Furthermore, the survey findings uncovered positive responses from prospective substance users.

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