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Transformation of Plastic Waste into Construction Material: Experimental Study of Concrete with Recycled Plastic Aggregates

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ABSTRACT: The research investigates the potential of utilizing plastic waste as recycled aggregate in the production of environmentally friendly concrete. The work is motivated by two major issues: the increasing volume of non-biodegradable plastic waste and the construction industry's heavy reliance on natural aggregates. The methodology involved collecting, cleaning, and shredding plastic packaging (e.g., coffee sachets, instant noodle wrappers) to be used as a partial replacement for aggregates in K-400 grade concrete. Plastic replacement ratios tested were 2.5%, 5%, and 7.5% of the total aggregate weight, with normal concrete without plastic serving as the control. Compressive strength tests were conducted at 28 days. Results indicate that the addition of plastic significantly reduces concrete compressive strength, with the highest decrease of over 50% observed at a 2.5% replacement ratio, although the concrete density remained relatively unchanged. Concrete with recycled plastic aggregate is potentially suitable for non-structural applications such as paving blocks or lightweight panels but is not recommended for structural components. The findings highlight the need for optimized mix design, surface treatment of plastic particles, and durability testing to improve the mechanical performance of recycled plastic concrete.

KEYWORDS: concrete, recycled plastic, aggregate, eco-friendly material

1. INTRODUCTION

Plastic waste has become one of the biggest environmental problems in the world. Data from environmental organizations show that over 300 million tons of plastic are produced each year, and most of it ends up as waste that pollutes the environment. In Indonesia, as one of the largest producers of plastic waste, plastic trash is often not managed properly, leading to pollution of the sea, rivers, and open land. This issue not only adversely affects the ecosystem but also human health and the socio-economic life of communities.

This research is important because it combines two urgent global environmental issues, namely the accumulation of non-biodegradable plastic waste and the high environmental impact of the construction industry. Unmanaged plastic waste can pollute ecosystems, threaten marine life, and pose risks to human health due to the accumulation of microplastics. On the other hand, concrete production drives unsustainable natural resource exploitation and contributes significantly to carbon dioxide emissions. Utilizing plastic waste as a mixture in concrete has the potential to reduce waste, curb the exploitation of natural aggregates, and support the principles of a circular economy as well as sustainable development goals.

Various previous studies have identified the potential use of plastic waste as a substitute aggregate in concrete to reduce environmental impact and dependence on natural resources. These studies suggest that plastic can decrease the density of concrete and improve resistance to cracking, but there are still limitations in the studies related to compressive strength, durability, and economic feasibility. This research gap indicates the need for more comprehensive further studies to ensure that such innovations do not compromise the structural quality of concrete. Therefore, this research aims to address the existing data and knowledge gaps, particularly in the context of application in the construction industry.

This research aims to explore the utilization of recycled plastic aggregates as a substitute in concrete mixtures, with the goal of producing environmentally friendly construction materials that are economically valuable and still meet optimal technical performance. Through a measurable experimental approach, this study will systematically analyze the influence of plastic substitution on the mechanical properties, durability, and efficiency of concrete in various application scenarios. The findings are expected not only to contribute to reducing the volume of plastic waste but also to strengthen the application of circular economy principles and achieve sustainable development targets. Overall, the contributions of this research are expected to provide a scientific and technical basis for the development and implementation of sustainable concrete technology on an industrial scale.

2. RESEARCH SIGNIFICANCE

The significance of this research lies in its potential to address two pressing global challenges simultaneously: the escalating accumulation of plastic waste and the urgent need for sustainable construction materials. By investigating the effects of recycled plastic aggregates on the mechanical properties of concrete, particularly compressive strength, the study provides valuable insights into the feasibility of incorporating plastic waste into concrete mixes without compromising structural performance. Furthermore, the research aims to produce viable concrete-based products utilizing recycled plastics, thereby contributing to waste reduction, resource conservation, and the advancement of eco-friendly construction practices. The findings are expected to offer innovative recommendations for the application of recycled plastic aggregates in concrete, supporting the transition toward more sustainable building materials and aligning with global sustainable development goals, especially in promoting responsible consumption, production, and resilient infrastructure.

3. METHODS

3.1 Location and Stages of Activities

This research is conducted at the Civil Engineering Laboratory of ISTN in South Jakarta. In general, this research starts from the planning stage, the concrete production process stage, the testing stage, the implementation stage, and the conclusion.

3.2 Preparation Stage

The preparation that will be carried out is socialization to the academic community of ISTN about plastic waste so that it is not disposed of carelessly. Next, plastic waste will be collected to be cleaned and chopped into pieces to be used as samples for eco-friendly concrete. The plastic waste will be mixed with other materials to create eco-friendly concrete. The type of plastic waste used is packaging plastics such as powdered coffee packaging, instant noodles, and similar items. The plastic waste will be sorted, cleaned, and then cut or chopped into small pieces.

3.3 The Stages of Concrete Production

The production of environmentally friendly concrete mixtures is conducted in the concrete materials laboratory owned by the civil engineering study program at ISTN. The concrete material uses instant concrete with a K-400 grade, which is mixed with water and plastic waste. These materials are mixed to create 12 test specimens as samples. Normal concrete with K-400 characteristics without plastic mixtures is made with 3 test specimens.

The following is the research flow that will be conducted:

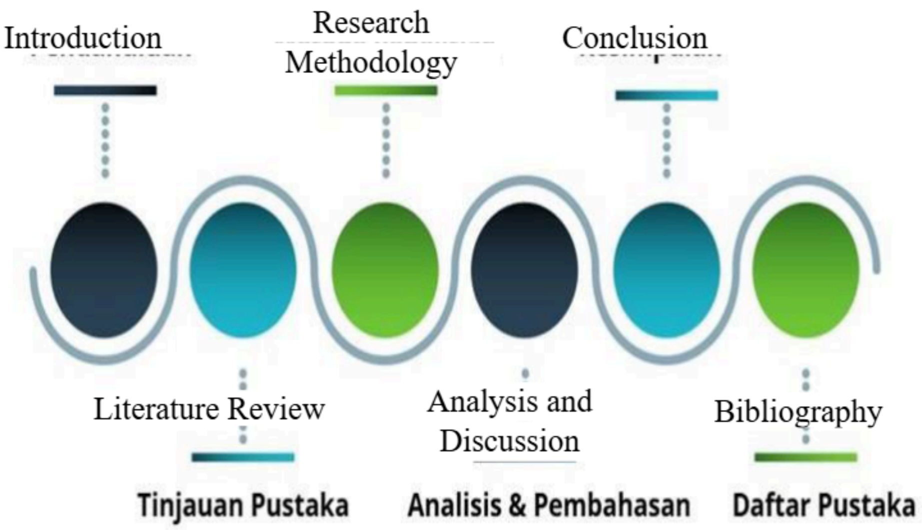

Fig. 1. Research Flow.

4. RESULTS

4.1 Material Testing

The sieve analysis testing on fine and coarse aggregates shows that both types of aggregates meet the standard grading specifications, with a sand fineness modulus value of 1.76 and SSD specific gravity of 2.49 g/cm³ for fine aggregate and 2.53 g/cm³ for coarse aggregate. The plastic waste used has a lower specific gravity (0.9–1.4 g/cm³) and is processed into particle sizes suitable to partially replace aggregates, thus potentially affecting the density, workability, and mechanical strength of the concrete.

4.2 *Job Mix Design*

Table 1. Calculation of the Composition of Normal Concrete Mix K-400

Material	Density (kg/m³)	Weight per Cylinder (kg)
Cement	515	2,73
Concrete Sand	645	3,42

Crushed Stone	1040	5.,51
Water	180	0,95

Table 2. Calculation of the Composition of Concrete Mixture with Normal and Plastic Waste

Type of Test Object	Weight of Waste	Number of Test Objects	Calculation
Normal	-	3 pieces	-
Type - 1	2,5 %	3 pieces	0,3 kg of plastic
Type - 2	15 %	3 pieces	0,6 kg of plastic
Type - 3	7,5 %	3 pieces	0,9 kg of plastic

The tested samples are 28 days old, with concrete compressive strength tests conducted using a crushing test tool, with the results attached.

Table 3. Concrete Compressive Strength

Type Benda Uji	Tanggal Pembuatan	Tanggal Pengujian	Umur	Massa Benda Uji	Bentuk Benda Uji (Silinder / Kubus)	Dimensi Panjang	Diameter	Lebar	Tinggi	Luas Bidang Tekan	Gaya Tekan	Kuat Tekan	Kuat Tekan Konversi Standar	Keterangan Pola Kehancuran
			(hari)	(gr)		(mm)	(mm)	(mm)	(mm)	(mm²)	(kN)	(N/mm²)	(kg/cm²)	
Normal														
1	09/05/2025	09/06/2025	28	11,84	Silinder		150		300	17662,5	615	34,82	419,51	Pecah dibagian tengah
2	09/05/2025	09/06/2025	28	11,84	Silinder		150		300	17662,5	610	34,54	416,10	Pecah dibagian tengah
3	09/05/2025	09/06/2025	28	12	Silinder		150		300	17662,5	590	33,40	402,46	Pecah dibagian tengah
1 (2,5%)														
1	09/05/2025	09/06/2025	28	11,91	Silinder		150		300	17662,5	285	16,14	194,41	Pecah dibagian atas
2	09/05/2025	09/06/2025	28	11,78	Silinder		150		300	17662,5	280	15,85	191,00	Pecah dibagian atas
3	09/05/2025	09/06/2025	28	11,8	Silinder		150		300	17662,5	280	15,85	191,00	Pecah dibagian atas
2 (5%)														
1	09/05/2025	09/06/2025	28	11,95	Silinder		150		300	17662,5	250	14,15	170,53	Pecah dibagian atas
2	09/05/2025	09/06/2025	28	11,95	Silinder		150		300	17662,5	255	14,44	173,94	Pecah dibagian atas
3	09/05/2025	09/06/2025	28	11,9	Silinder		150		300	17662,5	250	14,15	170,53	Pecah dibagian atas
3 (7,5%)														
1	09/05/2025	09/06/2025	28	11,92	Silinder		150		300	17662,5	240	13,59	163,71	Pecah dibagian tengah
2	09/05/2025	09/06/2025	28	11,96	Silinder		150		300	17662,5	245	13,87	167,12	Pecah dibagian tengah
3	09/05/2025	09/06/2025	28	11,94	Silinder		150		300	17662,5	240	13,59	163,71	Pecah dibagian tengah

5. DISCUSSION

Data on compressive strength testing at 28 days of age, here is a comprehensive review of the research results:

1. Normal Concrete Performance
   Average Compressive Strength:(34.82 + 34.54 + 33.40) / 3 = 34.25 N/mm²
   Consistency: The compressive strength values across samples are relatively uniform (range: 33.40–34.82 N/mm²), indicating good material homogeneity.
   Failure Pattern: All samples broke in the middle → consistent with the ideal failure pattern of normal concrete under centric compressive loads.
2. The Influence of Plastic Addition
   The largest decrease occurred in the addition of plastic at 2.5% (53.4%). Additions of >2.5% (5% and 7.5%) only reduced the compressive strength by an additional 5–7%. The mass tends to be stable (11.78–12.00 gr), indicating that plastic functions as a partial replacement for aggregate without significantly changing the density.
3. Pattern of Destruction
   Plastic 2.5% and 5%: Failure at the top → indicates segregation of plastic material to the surface, creating a weak zone.
   Plastic 7.5%: Returns to the middle pattern → plastic distribution is more uniform, but strength remains low due to weak cement-plastic bond.
4. Technical Implications
   Negative Impact: Plastics >2.5% are not recommended for heavy load-bearing structures (e.g.: columns, beams).
   Limited Application Potential: Suitable for non-structural applications (paving blocks, light panels) if the strength target of >15 N/mm² is achieved.
   Optimization: Experiments with plasticizers or surface treatment of plastics are needed to improve adhesion.

6. CONCLUSIONS

The addition of plastic reduces the compressive strength of concrete by over 50%, with the highest decrease at a concentration of 2.5%. Although it has potential for recycling waste, its application is limited to non-structural elements. The consistency of the destruction pattern indicates the need for optimization of material distribution to reduce segregation.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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