Utilizing Recycled Polyethylene Terephthalate Waste in Geopolymer Concrete Applications

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ABSTRACT

Concrete has experienced a marked increase in usage for road construction over the past decade, largely due to its durability. This study proposes an innovative method for producing eco-friendly and sustainable cement mortar, using municipal waste and industrial by-products. The study investigates the use of Polyethylene Terephthalate (PET) plastic waste as a fiber to enhance the mechanical characteristics of geopolymer concrete, which is based on Fly Ash (FA) and Rice Husk Ash (RHA). The investigation focused on the mechanical characteristics of geopolymer concrete, including its flexural and compressive strengths. The study incorporated four distinct geopolymer concrete mixtures containing PET plastic waste into the fly ash and rice husk ash-based geopolymer concrete: 0% PET plastic waste (SN), 0.25% PET plastic waste (SA), 0.50% PET plastic waste (SB), and 0.75% PET plastic waste. Using a 100 mm x 100 mm x 400 mm block for flexural strength testing and a 10 cm x 20 cm cylinder for compressive strength testing, the tests were conducted seven- and twenty-eight-days following air curing. The flexural test results indicated a decline in average flexural strength value with every 0.25% PET addition, reaching a 6.48% decrease. Compression testing revealed a negative correlation between the addition of PET and the compressive strength of the material. Specifically, an increase of 0.25% to 0.5% in the PET content resulted in an average reduction of 24.22% in compressive strength. Conversely, the compressive strength exhibited an increase of 10.91% between the 0.75% and 0.5% range of PET.

Keywords-PET plastic waste; fly ash; rice husk ash; geopolymer; pavement application

I. INTRODUCTION

The construction of infrastructure is of significant importance for the promotion of economic progress within a nation. Pavement, a component of infrastructure, can be categorized as either rigid or flexible. Globally, cement concrete is the material of choice for the production of rigid pavements. In comparison to flexible pavement, cement concrete pavement possesses superior strengths, including enhanced strength and durability. However, it is important to note that cement concrete pavement exhibits deficiencies in terms of its flexural strength, ductility, and energy absorption capabilities when compared to alternative materials. Additionally, the use of cement concrete pavement contributes to global warming through the emission of substantial CO_2 emissions [1, 2]. Consequently, there is a growing interest among researchers in exploring the potential of using waste resources to enhance the quality of pavement materials. Their objective is to determine the best practices that align with global sustainable development objectives [3, 4]. The global conversation surrounding environmental concerns has gained significant momentum. These concerns have been incorporated into the development plans of virtually all industries, including the industrial sector. The numerous instances of natural devastation resulting from human exploitation of nature underscore the inextricable linkage between environmental degradation and the prevailing environmental conditions [5]. The significance of fossil fuels, such as coal and oil, as primary energy sources for the transportation technology industry and production drivers, is increasing. However, it should be noted that fossil fuels are non-renewable energy sources that require millions of years to develop. Moreover, the waste byproducts of fossil fuels, most notably coal, have the potential to contaminate the environment. Moreover, the construction sector requires a substantial amount of energy, consequently leading to the generation and disposal of post-consumer waste. On an annual basis, approximately 3.6 billion tons of Portland cement are produced worldwide, constituting approximately 6% of all CO_2 emissions attributable to human activity. The magnitude of the greenhouse gas problem caused by cement manufacturing is due to the notable increase in population, infrastructure, and industrial activity, particularly in developing nations with high demand for cement and concrete [6]. In response to this challenge, authors in [7] pioneered the development of sustainable and inorganic geopolymer concrete. This innovative material is produced by combining alkali activators and industry-generated waste materials. Potassium hydroxide (KOH) and potassium silicate (K_2SiO_3) or sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) are potential alkali activators. Noteworthy industrial by-products, such as FA, silica fume, slag, and rice husk ash, have been identified as promising components in the creation of geopolymer concrete [8]. The amalgamation of these components in the creation of geopolymers is a rational approach. The use of an alkali activator has been demonstrated to result in the formation of a structurally robust 3D polymer chain [9]. Consequently, the incorporation of FA in the fabrication of geopolymer concrete can contribute to a reduction in atmospheric CO_2 emissions, thereby providing a sustainable alternative for waste usage. It has been demonstrated that both compressive strength and splitting tensile strength increase with rising molarity. However, studies have shown that geopolymer concrete exhibits greater brittleness compared to traditional concrete [10].

Research has demonstrated the use of agricultural by-products, such as RHA, as supplementary materials or cement alternatives. A substantial body of research has identified the presence of amorphous silica in RHA. The finer the RHA particles, the more pronounced the filler effect, and the greater the silica release, leading to heightened pozzolanic reactivity. The incorporation of RHA has been shown to remarkably augment the flexural strength of concrete. According to authors in [11], concrete's flexural strength increases by 10–30% for every 20% increase in RHA particle fineness. Additionally, RHA has been demonstrated to enhance the strength and durability of concrete. However, it is crucial to note that the increasing amount of waste generated by industrial and service sectors has led to significant environmental concerns. PET is a prominent example of a plastic waste that has been widely produced. In landfills, PET typically requires approximately 500 years to decompose, and its incineration can lead to significant environmental concerns, including pollution. Consequently, numerous studies have investigated the effects of incorporating PET into concrete, demonstrating that it can serve as a reinforcing material, partially replacing fine or coarse aggregates in concrete construction [12]. This study examined the use of geopolymer concrete, incorporating varying percentages of PET plastic fibers (0%, 0.25%, 0.5%, and 0.75% of the volume) and FA and RHA. The incorporation of FA, RHA, and PET plastic fibers was undertaken to ascertain the mechanical properties of geopolymer concrete, encompassing its compressive and flexural strengths. The compressive and flexural strengths of the geopolymer concrete were evaluated after 7 and 28 days of air curing.

II. SCOPE OF THE STUDY

A multitude of research findings indicate that the usage of FA and RHA materials, in conjunction with the incorporation of PET plastic fibers into geopolymer concrete, signifies a promising trend in the mitigation of coal waste. Notably, coal waste continues to be a significant concern in Indonesia, where it is extensively employed as a primary energy source in power plants. Moreover, Indonesia stands as the second-largest contributor to this process, a distinction attributable in no small part to the substantial presence of Indonesian plastic. The incorporation of PET plastic fibers in optimal proportions has been demonstrated to enhance the compressive strength of geopolymer concrete. Despite prior research on their use in concrete applications, the current study focuses on assessing the mechanical properties and environmental impact of FA and RHA based on recycled plastic waste fiber geopolymer concrete.

III. MATERIALS AND METHOD

A. Aggregate

The experiment was conducted at Hasanuddin University's Structure and Material Laboratory, which is affiliated with the Civil Engineering Department of the Faculty of Engineering. The Indonesian National Standard (SNI) serves as the benchmark for the components utilized in concrete mixtures. The ensuing analysis of the physical properties of Coarse Aggregate (CA), composed of crushed stone, and fine aggregate, consisting of sand, is presented in Table I.

TABLE I. CHARACTERISTICS OF AGGREGATE

Types of Testing	Method		Results	
	CA	Fine Aggregate	CA	Fine Aggregate
Fineness modulus	ASTM C136 – 06		7.0	2.4
Sludge content (%)	ASTM C117 – 23		3.1	4.6
Volume weight dense condition (kg/Lt)	SNI 03 – 4804: 1998		1.52	1.44
Volume weight loose condition (kg/Lt)			1.37	1.342
Apparent specific gravity	SNI 1970: 2016		2.71	2.56
Dry specific gravity			2.68	2.43
Saturated surface dry specific gravity			2.69	2.48
Water absorption (%)			0.4	2.1
Organic content	-	SNI 2816: 2014	-	No. 2
Abrasion (%)	SNI 2417: 2008	-	27.8	-

The loose volume weight of the fine aggregate material does not meet the established standards, according to an examination of its properties. Therefore, a better handling and storage technique must be used when using fine aggregate material. To avoid excessive contamination and deterioration of quality, this method should be stored in a dry place. To improve the quality of concrete, we also use additives such as retarders and superplasticizers. When the properties of the CA material are examined, it is found to be below the required standards, so aggregate washing is required to reduce the sludge content and make it ready for reuse in the mixing of geopolymer concrete. In addition, neither the bulk density of the solid nor the loose condition meets the established requirements, so a better way of handling and storing the CA material must be used. To avoid excessive contamination and quality degradation, we must ensure that this approach is used in a dry atmosphere. We also use additives such as retarders and superplasticizers to improve the properties of concrete.

B. Fly Ash (FA) and Rice Husk Ash (RHA)

FA from the Jeneponto power plant in South Sulawesi, Indonesia, served as the main constituent of the geopolymer concrete. Other components included PET plastic, crushed stone up to 20 mm, river sand, and RHA. Scanning Electron Microscope (SEM) analysis of FA and RHA particles is shown in Figures 1 and 2.

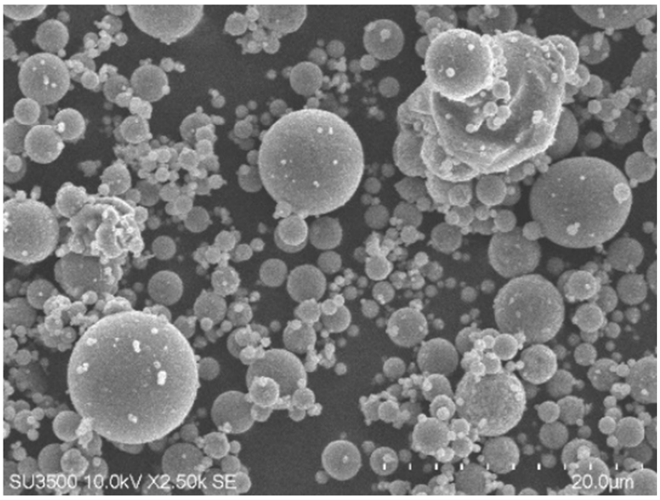

Fig. 1. SEM analysis of FA.

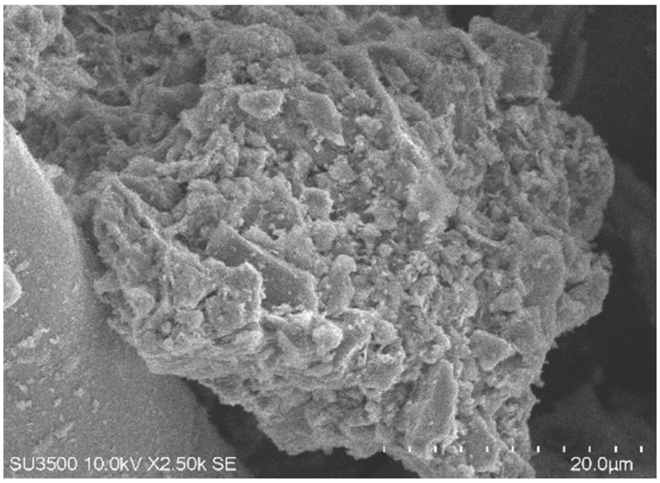

Fig. 2. SEM analysis of RHA.

The presence of tiny, spherical particles with a rounded shape is shown by the detection of FA. The RHA particles are flaky and permeable. The chemical composition of both FA and RHA is listed in Table II. FA is classified as class C according to ASTM C618-19 based on the chemical composition determined by X-ray Fluorescence (XRF) test results. The findings of the FA class type analysis are displayed in Table III. The results indicate that the FA examined had a CaO concentration of 26.16 (more than 18%) and a SiO_2 + Al_2O_3 + Fe_2O_3 content of 30.72%, 16.27%, and 8.74%, respectively. These values exceed 50% and fall below 70%. Consequently, the Bosowa Energi PLTU Jeneponto FA is classified as class C. The microstructure testing of the RHA material revealed a predominant chemical composition of 92.93% SiO_2. It is hypothesized that the elevated SiO_2 concentration will enhance the strength of the geopolymer concrete.

TABLE II. CHEMICAL COMPOSITION OF FA AND RHA (% BY MASS)

No.	Oxides (%)	Materials	
		FA	RHA
1	SiO_2	30.72	92.93
2	Al_2O_3	16.27	1.17
3	Fe_2O_3	8.74	0.33
4	CaO	26.16	0.45
5	MgO	10.32	0.88
6	K_2O	0.75	1.30
7	P_2O_5	0.00	0.79
8	SO_3	4.22	0.64
9	LOI	1.62	1.28

TABLE III. FLY ASH CLASS TYPE INSPECTION RESULTS

No.	Classification	Results of inspection	Class C
1	Silicon dioxide (SiO_2) + aluminum oxide (Al_2O_3) + iron oxide (Fe_2O_3) min., %	54.98	50.00
2	Calcium oxide (CaO), %	26.16	> 18.0

C. PET Plastic Waste

In this experiment, a PET plastic bottle, which contains a long chain of ethylene monomers (IUPAC: ethene), was used. Ethene, represented by the chemical symbol C_2H_4, has the formula: CH_2-CH_2--N. During the polymerization of ethene, two CH_2 groups are bonded together to form polyethylene. PET is a brown plastic that is derived from petroleum. Its mechanical properties include strength, exceptional flexibility, a slightly oily surface, and a moderate amount of transparency. At 600 °C, it exhibits remarkable resistance to chemical compounds. Additionally, this type of plastic is easy to make, dissolves easily in mixtures, has a specific gravity of 0.91 gr/cm^3 to 0.94 gr/cm^3, and provides good resistance to water vapor.

D. Research Design

The geopolymer concrete used a Na_2SiO_3 to NaOH ratio of 2, employing sodium silicate (Na_2SiO_3) and 10 M sodium hydroxide (NaOH) as alkali activators. The ratio of paste to total aggregate was 6:5, and the ratio of FA to alkali activator was 69:31. For each modification, 5% volumes of RHA were used in place of FA. The incorporation of PET plastic, with dimensions ranging from 1 mm to 3 mm in width and 2.5 cm in length, at concentrations of 0%, 0.25%, 0.50%, and 0.75%, designated as SN, SA, SB, and SC, respectively, was undertaken to enhance the bending capabilities of the geopolymer concrete. The objective of incorporating PET plastic waste in proportions of 0.25%, 0.50%, and 0.75% was to enhance the mechanical properties of geopolymer concrete by improving tensile and flexural strength. Through these variations, the optimal amount of PET can be ascertained, thereby enhancing crack resistance, durability, and load-bearing capacity. The gradual increase in PET content enables researchers to assess the equilibrium between strength enhancement and potential concerns, such as fiber agglomeration and diminished workability. The composition of geopolymer concrete is shown in Table IV. Three standard cylinder specimens, each measuring 100 mm in diameter and 200 mm in height, were cast and tested following seven and twenty-eight days of moist curing. The materials used in this investigation and the moist curing process carried out in the laboratory are presented in Figures 3 and 4, respectively.

TABLE IV. COMPOSITION OF GEOPOLYMER CONCRETE (KG/M^3)

		Code specimens			
No.	Materials	SN	SA	SB	SC
1	FA	857.68			
2	RHA	45.14			
3	CA	654.55			
4	Fine aggregate	436.36	432.91	429.46	426.01
5	Alkaline activator				
	10 M NaOH	135.42			
	Na_2SiO_3	270.85			
6	Retarder	1.81			
7	Superplasticizer	9.03			
8	PET	0	3.45	6.90	10.35

The SNI 2847:2019 standard was applied during the treatment of the test specimens, with all variations in this investigation being exposed to moist curing. This process involved storing the test specimens in an environment with air at 20°C and 60% humidity until the designated test day [13].

E. *Slump Test Method*

The concrete slump test method (SNI 1972:2008) and the slump flow test standard (ACI 1611M-05) were used in this study to conduct the slump test on fresh concrete. The viscosity level of the concrete mixture was determined using the slump test. Viscosity is defined as the ease with which concrete can be handled, including its capacity to be moved, mixed, poured, and packed down without cracking or segregation. The height at the center of the concrete's top surface diminishes after the slump test mold is elevated [14]. The fresh concrete mixture is inserted into a mold with a truncated cone shape, with the largest cone hole facing upwards, as per the slump test procedure outlined in SNI 1972:2008. It is imperative to exercise caution during the filling process to avoid piercing or compacting the concrete. Additionally, it is crucial to ensure the integrity of the mold remains intact throughout the procedure. To ensure unobstructed concrete flow, the concrete surrounding the base of the mold should be removed, and the concrete surface at the top of the cone should be leveled using a levelling rod. The diameter of the distribution is measured at a radius perpendicular to the initial diameter measurement line, subsequent to vertical elevation of the mold and a period of waiting to allow the concrete to cease flowing. Subsequently, the research computed the slump value in accordance with ACI 1611M-05. This process involved determining the values of d1 and d2 and then calculating their mean. The precision of the average value of the two diameters is recorded to the closest 5 mm. For the creation of variants of geopolymer concrete samples, the intended slump flow is between 50 cm and 75 cm. The measurement of slump in geopolymer concrete is demonstrated in Figure 5.

Fig. 3. Materials of geopolymer concrete.

F. *Compressive Strength Test Method*

The compressive strength of concrete was determined through a series of experiments using a cylindrical test item measuring 100 mm by 200 mm. The tool employed in this study was a 1000 kN Tokyo Testing Machine (TTM), and the compressive load was measured and confirmed using a 500 kN load cell. The application of compressive stress to the test object was expected to induce its collapse. Consequently, the greatest stress at which the test object collapses is the compressive strength. The mean compressive strength findings were obtained for each of the three test item variations of the compressive strength test. The test was conducted on cylindrical concrete specimens that were 7 and 28 days old. The configuration for testing the compressive strength of geopolymer concrete is shown in Figure 6.

Fig. 4. Curing of specimens.

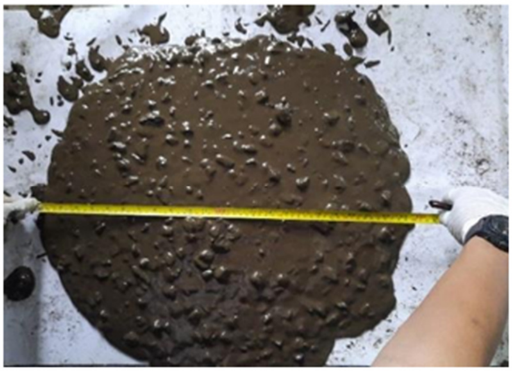

Fig. 5. Slump flow testing.

Fig. 6. Compressive strength test.

G. Flexural Strength Test Method

This test is used to ascertain the maximum amount of force that a concrete block can withstand perpendicular to its axis before it fractures. Concrete blocks that have been cast 7- and 28-days prior are used in the flexural strength tests. The configuration for evaluating the flexural strength of geopolymer concrete is presented in Figure 7.

Fig. 7. Flexural strength test.

IV. RESULTS AND DISCUSSION

A. Slump Test Analysis

In order to ascertain the workability level of the concrete mixture, slump testing was performed for each fresh geopolymer concrete mixture change. Determining the workability level of the concrete mixture necessitates the assessment of slump value. The outcomes of these tests are presented in Table V.

TABLE V. SLUMP TEST VALUE

No.	PET Percentage Variation (%)	Slump (cm)
1	0 (SN	60
2	0.25 (SA)	64
3	0.50 (SB)	67
4	0.75 (SC)	58

The fresh concrete slump test, reveals a propensity for increasing PET variance from 0% to 0.50%, accompanied by subsequent decreases in PET variation from 0.75% to 0.50%. Following the creation of concrete samples, it was observed that the slump value ranged from 50 to 75 centimeters. Additionally, PET changes of 0%, 0.25%, 0.50%, and 0.75% were found to comply with the stipulated slump flow requirements as outlined in ACI 1611M-05. Conversely, an increase in PET percentage, ranging from 0.25% to 0.5%, results in an upward slope of the slump value, with a 6.72% increment observed at 0.25% PET and a 5.51% rise at 0.5% PET. Conversely, a decline in PET percentage by 0.75% leads to a significant decrease in slump value, reaching -15.52%. The workability of concrete to stir, transport, pour, and compact without producing segregation of the constituent material was demonstrated by a slump test that was conducted to ascertain the consistency of concrete mixtures. It is imperative that the consistency of the concrete mixture aligns with the established standards for the quality of the final product.

B. Density Test Analysis

The results of the density tests conducted on test specimens of geopolymer concrete, aged seven and twenty-eight days, are presented in Figure 8. Concrete density testing, also known as concrete-specific gravity testing, is a critical phase in evaluating the characteristics and quality of concrete. The mass of concrete per unit volume is represented by its density, which is frequently expressed in kg/m2. To perform the test, a cylindrical concrete specimen is prepared and weighed using an accurate scale. It is imperative to take precise measurements of the concrete test specimen's dimensions to ensure the accuracy of the results. Using the relevant calculation, the test specimen's volume is determined and the ASTM C138/C138M 17a test was used as a guideline [15].

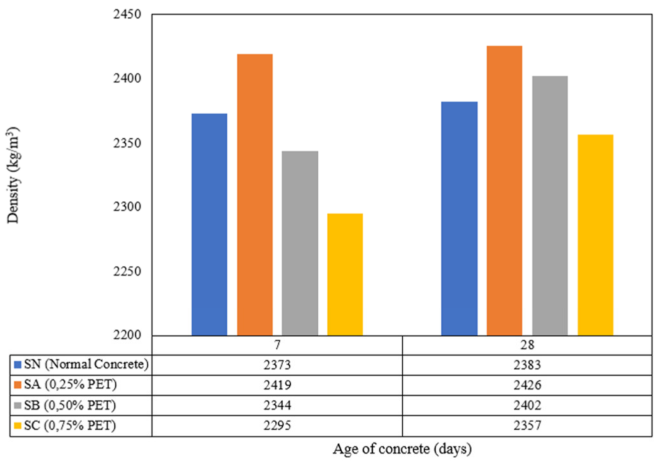

Fig. 8. Density test results.

C. Compressive Strength Test Analysis

This study used 100 mm by 200 mm cylinders at 7 and 28 days of age to assess the compressive strength in accordance with ASTM C39/C39M-01 [16]. In the field of structural design, compressive strength is imperative. As shown in Figure 9, the compressive strength of the geopolymer paste increased with age for all PET plastic addition permutations, exhibiting a similar trend to that of concrete in general.

This observation signifies that the geopolymer paste's polymerization process is progressing in a satisfactory manner. However, the incorporation of PET plastic in geopolymer concrete has been observed to result in a decline in compressive strength. After seven days, a 19.19% and 35.58% decrease in compressive strength was observed with the addition of 0.25% and 0.5% PET plastic fiber, respectively. However, the strength demonstrated an increase of 27.05% when 0.75% PET plastic was incorporated. The findings from the 28-day compression test were consistent with these observations. The addition of 0.25% and 0.5% PET plastic resulted in a decrease in compressive strength by 33.62% and 15.17%, respectively, while the incorporation of 0.75% PET plastic led to an increase of 10.91%. The histogram graph displays the compressive strength test results for concrete that was aged 7 and 28 days with four changes. The figure reveals that the SA variation concrete demonstrates higher compressive strength compared to the other variations at both 7 and 28 days. In contrast, the SB sample to SC exhibited a 27.05% growth after seven days of an average addition of PET plastic fiber, while the SN sample to SA-SB demonstrated a decrease of 19.19% and 35.58%, respectively. Furthermore, at 28 days, the SB sample to SC exhibited a growth of 10.91%, while the SN sample to SA-SB demonstrated a decrease of 33.62% and 15.17%, respectively, with an average addition of PET plastic fiber. Theoretically, the test findings indicate that after every 0.25% PET is added, the compressive strength values decrease. The mean percentage reduction in compressive strength for the SA and SB variations at 7 and 28 days of age was 27.39% and 24.40%, respectively. In contrast to the SB variation, the SC variant exhibited an increase in compressive strength of 27.05% and 10.91%, respectively, defying the anticipated downward trend. The procedure and results of authors in [16] are analogous because they encountered difficulties working with the concrete samples. The concrete mixer's constrained capacity precluded the simultaneous production of all the requisite PET plastic fiber additions, necessitating the division of the concrete mixture into multiple stages. The usage of a single mixing cycle yielded a total of 10 samples.

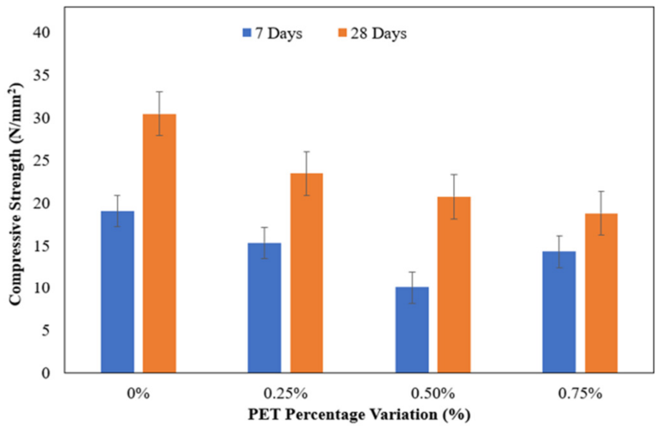

Fig. 9. Compressive strength test results.

A decline in compressive strength was observed in a series of preliminary tests that incorporated PET plastic into the concrete mixture. However, the incorporation of 0.75% PET plastic in this study constituted an anomaly, resulting in enhanced compressive strength outcomes. The reduction in compressive strength, which hindered the compaction of the geopolymer concrete, might have been precipitated by a brief setting period. This outcome aligns with those reported by authors in [17] who observed similar effects when PET plastic was used as a substitute for fine aggregate in concrete. The presence of PET plastic, characterized by its size and smooth surface, may hinder the formation of complete interlocking between aggregates, consequently leading to a reduction in compressive strength. In comparison to conventional concrete, geopolymer concrete has been shown to exhibit superior mechanical properties, particularly with regard to higher early strength, enhanced durability, and augmented resistance to chemical degradation. Conventional concrete relies heavily on cement as a binding agent, whereas geopolymer concrete uses industrial by-products such as FA and RHA, thereby significantly reducing its carbon footprint. In terms of environmental impact, geopolymer concrete has been shown to generate up to 80% less CO_2 emissions compared to traditional concrete, thereby positioning it as a more sustainable alternative. While the initial material cost may be marginally higher, the long-term benefits, including enhanced durability, reduced maintenance needs, and lower embodied carbon, contribute to significant cost savings over the project's lifetime. Furthermore, the incorporation of PET plastic waste has been shown to enhance the performance of geopolymer concrete, thereby addressing concerns regarding plastic pollution. Consequently, geopolymer concrete emerges as a promising alternative to conventional concrete for infrastructure projects, demonstrating a commitment to environmental sustainability, durability, and cost-effectiveness. A comparative analysis of the percentage differences between the SA, SB, and SC code test specimens revealed that the SN code test specimen exhibited the highest compressive strength value at 28 days, with values of 33.62%, 48.79%, and 36.80%, respectively. The SN variant demonstrated the highest compressive strength among the test specimens. A discernible downward trend is evident from the SN specimen to the SA specimen. This observation aligns with the findings reported by authors in [17]. The SC variation, particularly the 0.5% PET addition, does not, as indicated by the test results, meet the minimum compressive strength criterion of 17 MPa required for structural applications as outlined in SNI 2847: 2019 concrete mixture into several phases; only ten samples were produced by a single mixing [18-20].

D. Flexural Strength Test Analysis

At 7 and 28 days of age, flexural strength tests were performed in accordance with the standard SNI 4431:2011 [19]. The flexural strength test results are presented in Figure 10. In general, an increase in PET results in a decrease in the flexural strength value of geopolymer concrete. At 7 days of age, the flexural strength values of geopolymer concrete with PET changes of 0.25%, 0.5%, and 0.75% of the concrete volume decreased by 15.20%, 23.63%, and 35.17%, respectively. At 28 days, the flexural strength values of geopolymer concrete with PET changes of 0.25%, 0.5%, and 0.75% of the concrete volume decreased by 16%, 16.03%, and 16.50%, respectively. Consistent findings were reported by authors in [21] where PET was used as a substitute for fine aggregate in concrete. It is well established that the incorporation of PET plastic bottle trash into concrete leads to a gradual decline in its flexural strength. Authors in [22] explored the use of PET plastic as a fine aggregate to similarly reduce the flexural strength of concrete. The findings indicated that the incorporation of PET plastic into concrete generally led to a reduction in its flexural strength. The extent of this decline increased in proportion to the amount of PET plastic added. In addition, the Indonesian highway specification SKH.1.5.24 (2023) stipulates that heavy traffic roads must possess a flexural strength of 4.1 MPa, medium traffic roads (collection roads) must have a flexural strength of 3.8 MPa, and light traffic roads (local roads) must have a flexural strength of 3.5 MPa [23, 24]. As shown in Figure 10, the flexural strength value of the amended concrete falls below the minimum requirements for utilization on light, medium, and heavy traffic roads. The behavior of the material is initially linear until it approaches the yield load, as evidenced by the graphs examining the relationship between load and deflection from experiments on various concrete mixtures. This observation is consistent across all specimens, including those modified with PET (SA, SB, and SC), as well as the unmodified geopolymer concrete (SN). As the volume of PET in concrete increases, Figure 10 demonstrates a corresponding decrease in load and deflection. This phenomenon is likely attributable to the excessive smoothness or uneven distribution of the PET surface, which could diminish the effectiveness of the bridging effect.

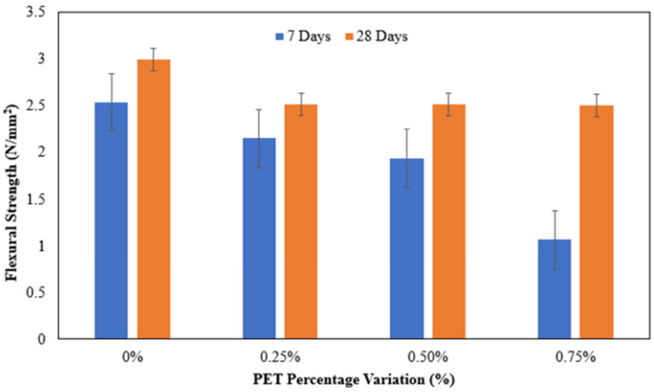

Fig. 10. Flexural strength test results.

V. CONCLUSIONS

The ensuing findings are derived from the results and discussion of geopolymer concrete manufactured from Fly Ash (FA) and Rice Husk Ash (RHA) with varying amounts of Polyethylene Terephthalate (PET) fibers added. The following conclusions can be drawn:

- All variations of geopolymer concrete exhibit adequate workability, as indicated by slump flow values ranging between 50 cm and 75 cm, which fall within the acceptable range for achieving a balance between ease of placement and stability.
- The incorporation of PET plastic, up to a maximum of 0.5% of the concrete's composition, results in a decline in compressive strength, although this strength increases with the passage of time. This phenomenon aligns with the density value of geopolymer concrete, which exhibits a decline with the incorporation of 0.5% PET plastic.
- Concrete's compressive strength increases with age; however, the addition of PET plastic fibers to the geopolymer concrete mixture results in a decrease in compressive strength. For every 0.25% PET addition to the

SA and SB compositions, an average decrease of 24.22% is observed; however, the SC composition increases by 10.91% in comparison to SB.

- As the proportion of plastic waste in the concrete mixture increased, the flexural strength test analysis exhibited a declining trend in flexural strength values. At 7 and 28 days, the 0.75% PET variation exhibited the least significant decrease, with 39.60% and 16.50% of normal geopolymer concrete (SN), respectively.
- It is imperative for future researchers to identify the most effective working approach to ensure precise and defect-free craftsmanship and concrete quality, particularly in large-scale production contexts, taking into account the limitations inherent to geopolymer concrete, such as its brief setting time and constrained mixer capacity.

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