SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V12I11P109

Volume 12 Issue 11, 110-120, November 2025
© 2025 Seventh Sense Research Group®

Original Article

Utilizing Wet Wipes Waste in Concrete: Analysis of Compressive Strength, Tensile Strength, and Absorption

Alia Salsabila Farhani[1], Nasruddin[2], Hartawan Madeali[3]

[1,2,3]*Department of Architecture, Faculty of Engineering, Hasanuddin University, Gowa, Indonesia.*

[2]*Corresponding Author : nasruddin@unhas.ac.id*

Received: 06 September 2025 Revised: 07 October 2025 Accepted: 05 November 2025 Published: 29 November 2025

Abstract - *This study explores the use of wet wipes waste as an additional fiber in concrete mixtures to improve mechanical performance and durability to support sustainable construction practices. The addition of fiber is divided into variations of 0.15%, 0.20% and 0.25% with a variation of 0% as the control concrete. Concrete performance was analyzed through the results of compressive strength, split tensile strength, and absorption tests using the wet curing method. The test results indicate that the addition of wet wipe fibers has a significant effect on the mechanical properties and durability of concrete. The 0.20% variation was shown to exhibit optimum performance in compressive strength equivalent to that of the control concrete, higher split tensile strength, and low water absorption, indicating an increase in resistance to cracking and structural densification. In contrast, the 0.15% and 0.25% variations reduced concrete performance due to increased porosity and fiber agglomeration. The integration of wet wipes waste into the concrete mix is the novelty of this study. Wet wipes, as a non-biodegradable material, pose a significant environmental challenge, but they have the potential to be used as concrete reinforcement fibers. This research not only focuses on improving concrete quality but also contributes to reducing waste distribution as a reusable material in the building and infrastructure sectors. This finding is significant, demonstrating the potential of wet wipe waste fibers as an additive in concrete to maximize the development of the sustainable construction industry.*

Keywords - *Absorption, Compressive strength, Concrete, Splitting tensile strength, Wet wipes waste.*

1. Introduction

The use of concrete in the construction industry has become commonplace, particularly in infrastructure development. Concrete is widely used for various structural applications and is a crucial material [1]. One parameter used to evaluate concrete quality is its compressive strength [2]. Concrete must undergo a perfect hardening or curing process to meet compressive strength requirements. Curing treatment can mature the mechanical properties and durability of concrete in a sustainable manner [3, 4].

In addition to compressive strength, the splitting tensile strength of concrete is also an important parameter in assessing the structural quality of concrete [5]. Concrete is inherently weak against tensile forces, and initial cracks in structural elements are often caused by tensile stresses exceeding the concrete's capacity. Therefore, splitting tensile strength testing is relevant in evaluating concrete's resistance to potential cracking [6]. Splitting tensile strength has a direct relationship with the crack resistance and flexural behavior of concrete, especially in structural elements such as beams, slabs, and columns [7]. Furthermore, concrete durability, or resistance to external environmental influences, is a crucial consideration in the development of modern construction materials. Concrete with good durability values will have a longer service life and require less maintenance [8]. One simple yet effective indicator for assessing durability is water absorption testing [9]. Concrete with low water absorption is more resistant to water infiltration and other harmful substances, thus minimizing the risk of premature damage due to reinforcement corrosion or chemical reactions [10, 11].

The development of the construction and building sector presents a new challenge in relation to environmental sustainability and degradation. The infrastructure sector contributes significantly to the creation of carbon emissions and waste, which are now increasing rapidly. Therefore, the global world is striving to explore and create new, environmentally friendly materials by applying the principles of a circular economy, namely, using and reusing waste into new resources [12]. One method or approach currently used is processing waste into additives in concrete.

The use of recycled materials in concrete production can reduce the amount of waste disposed of [13]. Various previous studies have been conducted to examine the use of waste in concrete, such as plastic waste, textile waste, and natural fibers. However, of the many uses of waste, there is not much research related to the use of wet wipes waste, which, in essence, wet wipes have unique characteristics where wet wipes are composed of cellulose and synthetic fiber, such as polyester, rayon, and polypropylene. The addition of certain fibers affects the properties or characteristics of the fibers, the ability to bind with cement paste, and the curing process applied. To date, there has been no comprehensive study examining the effect of adding wet wipes waste to concrete on the compressive strength, splitting tensile strength, and durability (absorption) of concrete using the wet curing method.

Several reasons underlying the use of wet wipes waste as an additive include that the fiber has the potential to strengthen the concrete microstructure, where the fiber effect can bridge the occurrence of microcracks by maintaining the tensile strength of the additive. This statement is in line with experiments that have been carried out related to fiber tensile strength testing, which shows that wet wipe fiber has quite good tensile strength, where the fiber can maintain its shape until it breaks within 15-30 seconds [14]. In addition, there is the potential for fiber to be able to perform internal curing, where the fiber can maintain cement hydration so that it can minimize porosity. Studies on this understanding note that its success depends on the size, additional method, dosage, and characteristics of the additive [15].

Wet wipes factories in Indonesia are in many areas, such as Mojokerto, Surabaya, Sidoarjo Regency, West Jakarta, and other locations. This indicates that wet wipes are a significant source of income for Indonesia. Due to its abundant availability from various processing industries, wet wipes waste has become the subject of research in this context. This waste will be utilized as additional concrete fiber to reduce the current surge in waste disposal.

This is based on a study conducted by Sigma Research of 1,200 mothers with children under 2 years old in 11 major cities in Indonesia. Some of these cities include DKI Jakarta, Surabaya, Semarang, Bandung, Balikpapan, Medan, and Makassar. Nearly 70% of mothers use wet wipes for their children's daily needs. Generally, mothers use 6-10 sheets of wet wipes per day, sometimes even more than 15 sheets per day [16]. Although the government has taken steps to improve waste management, more efforts are needed to address the problem.

El Aal et al. [17] observed the addition of Polypropylene fibers (PP), Personal Protective Equipment (PPE) from COVID-19 waste with an additional percentage of 0.5%, 1%, 1.5%, 2% and 2.5%. The study resulted in increased mechanical properties at addition percentages up to 2% but decreased from additions above 2% due to the formation of air cavities and weakening of the bond between the fiber and concrete. Kilmartin-Lynch et al. [18] examined the feasibility of adding Polypropylene (PP) fibers from disposable mask waste from COVID-19 with an addition percentage of 0.10%, 0.15%, 0.20% and 0.25%. The study showed an increase in the mechanical properties of concrete at a percentage of 0.20% but a decrease at a percentage of 0.25% due to increased porosity and reduced bonding between the fiber and cement. Bahij et al. [19] studied the performance of concrete with the addition of 0.25%, 0.50% and 0.75% nonwoven PET tissue fiber and the addition of superplasticizer. The study showed a decrease in the mechanical properties of concrete. There was an increase in water absorption, which caused the formation of weak zones that increased porosity.

Several studies have examined the effect of waste addition to concrete; there is still a knowledge gap regarding the effects of using wet wipe waste. In the context of sustainable development, research on the addition of new materials to concrete is relevant. This aligns with efforts to reduce carbon footprints, reuse waste, and develop more environmentally friendly construction technologies. Recycling or reusing waste can reduce negative impacts on the environment through resource control and reducing carbon emissions [12].

This study is planned as a preliminary or basic study to determine the effect of adding wet wipes waste on the mechanical properties of concrete, such as compressive strength, split tensile strength, and absorption, as fundamental indicators that determine the internal quality of concrete, in relation to the initial age of concrete. Long-term durability testing in depth, such as a chloride penetration test, carbonation test, or sulfate test, has not been carried out in the study. This study is focused on as a preliminary study to build a basic understanding of how wet wipe fibers interact with cement paste. It is hoped that this study can be a basis for further research on the durability aspect of service life. The findings of this study will contribute to the establishment of new standards for the use of waste as an additive in concrete, which will ultimately improve sustainability in the construction industry [20].

2. Materials and Methods

The concrete was mixed with wet wipes waste from household waste. For variations in concrete addition, 0.15%, 0.20%, and 0.25% of the cement weight were used, with a 0% concrete variation as a reference. Concrete testing was carried out using the compressive strength and splitting tensile test methods at the ages of 7, 14, and 28 days, as well as concrete absorption testing at the age of 28 days using the wet curing method. The concrete mold used was a cylindrical shape with a diameter of 10 cm and a height of 20 cm. The equipment used for concrete testing was a Universal Testing Machine (UTM) for compressive strength and splitting tensile tests. Meanwhile, absorption testing was carried out by oven-drying the specimen until it reached saturated weight.

2.1. Material

The materials used, such as gravel and sand, are first tested according to Indonesian National Standards (SNI) to determine whether they are suitable for use. Meanwhile, the cement used in this study was Portland Composite Cement (PCC). The results of the aggregate characteristics test can be seen in Table 1.

An organic content test is also performed to determine the quality of the sand. This test involves mixing the fine aggregate with a NaOH solution and then allowing it to stand for 24 hours. The organic content will show color standard number 2, indicating that the aggregate is suitable for use in concrete. The collected wet wipes waste is cleaned by washing it thoroughly with soap, then adding sodium bicarbonate to remove any remaining dirt. It is left for approximately 4 hours, followed by rinsing the waste until it is clean and there are no bubbles. The waste is then soaked again in a solution of H_2O_2 3% (re-dissolved with distilled water until a solution is obtained, H_2O_2 0.5%) to remove any remaining residue from the waste, then let it sit for approximately 24 hours, then rinse thoroughly, then dry and cut the waste into 2x15mm fibers. After the cutting process is complete, the fiber is washed again with clean water to remove any remaining dirt from the cutting process. Then, the fiber is soaked to check the pH of the soaking water until it reaches a neutral pH, indicating it is free of chemical residue. The fiber is then rinsed again until clean and oven-dried. The fiber is ready for use in Figure 1.

Fig. 1 Wet wipes fibers

2.2. Mixing Method

The concrete is mixed using a mixer with a maximum mixing time of 5 minutes for normal fresh concrete. Materials such as coarse aggregate, fine aggregate, cement, and water are added gradually. The mixing principle for concrete with fiber is the same as for normal concrete. However, the wet wipe fibers are added after the fresh concrete is mixed and then removed from the mixer. Fresh concrete is removed first to prevent the fibers from sticking to the concrete mixer walls, which can cause uneven mixing. The fiber mixing method involves adding ¼ of the fiber to each batch and mixing with a hand mixer. The fiber addition process is the primary focus, as it must be done carefully to prevent segregation in the concrete.

In the concrete molding process, compaction is carried out using a compactor rod by ramming the fresh concrete 25 times, then reducing the remaining air bubbles trapped in the fresh concrete and ensuring that the concrete is evenly distributed using a vibrator.

Table 1. Summary of aggregate characteristics test results

Aggregate Characteristics	Coarse Aggregate	Fine Aggregate
Volumetric Weight Release Condition (kg/L)	1.60	1.46
Volumetric Weight Solid Condition (kg/L)	1.65	1.57
Coarseness/Fineness Modulus	6.13%	1.42%
Type Weight Rainfall (kg/m^3)	2.52	2.28
Type Weight Dry Surface (kg/m^3)	2.53	2.33
Type Weight Fake (kg/m^3)	2.56	2.39
Absorption	0.70%	2.00%
Water Rate	0.67%	2.04%
Mud Rate	0.30%	4.00%

2.3. Mix Proportions

The concrete proportions are calculated based on the Development Of Environment (DOE), with details listed in Table 2. The water-cement ratio (w/c) is 0.48, with a concrete quality of 20 MPa. The fiber content is calculated based on the weight of the cement.

Table 2. Mix proportion

Materials	Weight of Materials (kg/m^3)
Cement	470.08
Water	205
Fine Aggregate	574.8
Coarse Aggregate	940.2

2.4. Sample

There are 56 concrete samples with variations and concrete ages of 7, 14, and 28 days in compressive strength and split tensile strength, while absorption at the age of 28 days, each of which amounts to 2 samples, which can be seen in Table 3. The determination of the sample is based on the results of the calculation of the coefficient of variation value from the results of concrete testing on compressive strength, split tensile strength, and durability according to the reliability of general concrete quality control guidelines [21]. A more in-depth explanation is presented in the results and discussion section.

Table 3. Description of the number of test specimens samples

Curing	Wet Wipes Content	Compressive Strength (Day)			Split Tensile Strength (Day)			Absorption (Day)	Total
		7	14	28	7	14	28	28	
Wet Curing	0%	2	2	2	2	2	2	2	14
	0,15%	2	2	2	2	2	2	2	14
	0,20%	2	2	2	2	2	2	2	14
	0,25%	2	2	2	2	2	2	2	14
									56

2.5. Life Cycle Analysis Standard

This study conducted a qualitative life cycle assessment to determine the benefits of incorporating fibers from wet wipes waste into concrete. This analysis was based on the EN 15804 standard [22] in a small laboratory setting.

3. Results and Discussion

3.1. Properties

3.1.1. Workalibity

The slump test results showed an increase in workability with the addition of wet wipe fibers. Normal concrete has a slump of 12 cm, while at 0.15% and 0.20% levels, the slump value increased to 14.5 cm and 18 cm (Table 4). This increase occurs because wet wipe fibers in Saturated Surface Dry (SSD) condition act as a water reservoir, releasing water during the mixing process, so that the mixture becomes more plastic, as can be seen in Figure 2. The highest slump value at 0.20% implies better workability and compaction, which directly reduces the amount of trapped air in the concrete. The slump decreased slightly compared to 0.20%. This is because the amount of fiber is too much, which increases internal friction and the potential for fiber agglomeration.

Table 4. Slump value

Wet Wipes Content	Slump (cm)
0%	12
0,15%	14.5
0,20%	18
0,25%	16

3.1.2. Content Weight

Based on the data tabulation, the concrete unit weight shows no significant changes. Therefore, it can be concluded that the addition of wet wipes fibers does not affect the concrete unit weight. The normal concrete weight without fiber addition is 2338 kg/m3 (Table 5).

Likewise, the variation of 0.15% fiber addition has the same value. Meanwhile, the variation of 0.20% and 0.25% fiber addition only has a reduction of 1.1% from normal concrete and concrete with 0.15% fiber addition, which indicates that the addition of fiber in small amounts does not provide a significant change in concrete density. Normal concrete according to SNI 03-2847-2002 [23] has a concrete weight between 2200 and 2500 kg/m3, which indicates that concrete with 0.15%, 0.20% or 0.25% fiber addition is still grouped into normal concrete based on its unit weight.

Table 5. Concrete weight results

Wet Wipes Content	Weight (kg)	Specific Gravity (kg/m^3)	Reduction (%)
0%	3.67	2338	0
0,15%	3.67	2338	0
0,20%	3.63	2312	1,1
0,25%	3.63	2312	1,1

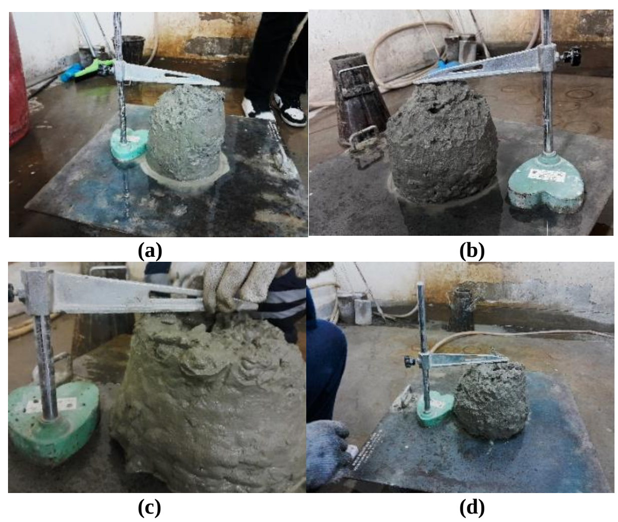

Fig. 2 Test results slump concrete: (a) Concrete 0%, (b) Concrete with 0.15% wet tissue fiber, (c) Concrete with wet tissue fiber 0.20%, and (d) Concrete with 0.25% wet tissue fiber

3.2. Compressive Strength Test

According to the results of the compressive strength test reviewed at the ages of 7, 14, and 28 days, the addition of wet wipe fibers as time increases in each variation provides quite significant results, which can be seen in Table 6 and Figure 3. However, at the initial age (7 days), variations in each fiber addition experienced a decrease in compressive strength caused by suboptimal cement hydration and the effect of fiber addition, which affects concrete density. In the following week (entering the age of 14 days), variations in fiber addition showed a recovery in compressive strength but were still below the results of the control concrete test.

Table 6. Summary of compressive strength test results

Wet Wipes Content	Curing Age (Day)		
	7	14	28
0%	20,064	23,248	30,000
0,15%	16,497	22,357	25,287
0,20%	18,471	21,210	30,000
0,25%	16,178	20,064	27,261

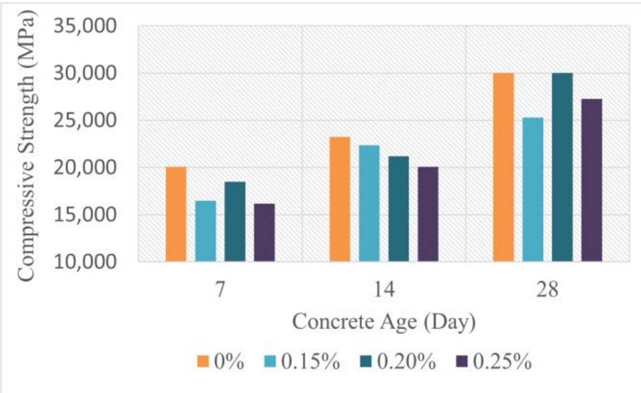

Fig. 3 Compressive strength test results graph at ages 7, 14, and 28 days

At the age of 28 days, a striking difference was seen, where the concrete variation of 0.20% fiber achieved the same compressive strength equivalent to the compressive strength achieved by normal concrete (30 Mpa), while variations of 0.15% and 0.25% experienced a decrease of 15.7% and 9.1% respectively, indicating that the 0.20% content achieved the most balanced condition between the water supply (internal curing) from the fiber and also the even distribution of fiber in the concrete mixture, so that the concrete hydration process took place perfectly and produced optimal final compressive strength. Therefore, it was concluded that the 0.20% fiber variation was the optimum dose that was able to maintain the quality of concrete equivalent to normal concrete. Meanwhile, lower or higher fiber content led to a decrease in the mechanical performance of the concrete.

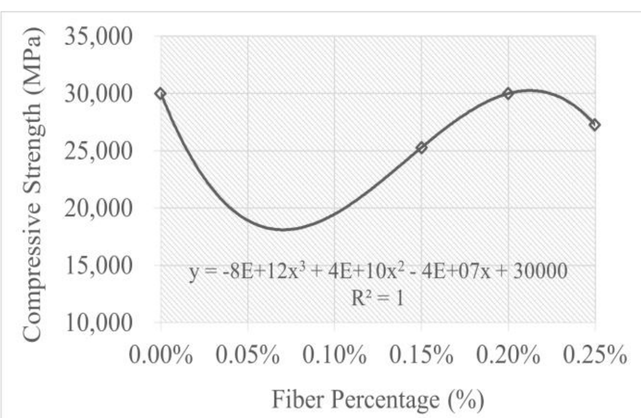

Fig. 4 Graphics polynomial optimum rate test strength press age 28 days

The derivative of the regression equation (Figure 4) obtained two stationary points, which showed the minimum point was at 0.07% fiber of 18.10 Mpa, while the optimum point was at 0.21% fiber with a compressive strength of 30.26 Mpa. The results of this equation indicate that the optimum point on the graph is in line with the test results at a content of 0.20% which shows a high compressive strength value. However, due to the minimal number of stationary points, the optimum value can be interpreted with an estimated variation that needs to be re-verified with additional testing on fiber content around the optimum area.

The ANOVA analysis Table 7 shows that the P-values for the effects of age and fiber indicate differences. The P-values for the effects of age and fiber are less than 0.05, but there is no interaction between the two based on the interaction column, which shows a P-value > 0.05.

This indicates that the addition of fiber to compressive strength is quite consistent at all ages. This finding indicates that the increase in compressive strength in concrete with the addition of fiber is stable as the concrete ages.

Table 7. Anova two-factor with replication of compressive strength

Factor	F	P-value	F crit
Curing age	74.752	1.68267E-07	3.885
Tissue content	5.012	0.017628364	3.490
Interaction	1.096	0.41816191	2.996

3.3. Split Tensile Strength Test

Splitting tensile strength testing showed an increase with increasing concrete age, starting from 7, 14, and 28 days (Table 8 and Figure 5). At the ages of 7 and 14 days, the test results tended to be lower than normal concrete, indicating incomplete cement hydration due to the addition of water, Saturated Surface Dry (SSD) to the concrete fibers, requiring a long time until the hydration process was complete.

Previous research has shown that wet tissue fibers break more easily when wet. This is because water entering the cellulose fibers causes hydrogen bonds to break, weakening the tissue. In other words, the fibers become slippery, reducing friction. Meanwhile, when dry, the fibers can increase their tensile strength by up to 98% due to the dried tissue forming a stiff, interlocking network [14].

However, at the age of 28 days, there was a significant increase, indicating that the fibers began to provide a positive contribution, as reviewed by the test results at variations of 0.20% and 0.25% exceeding the tensile strength of normal concrete.

This indicates that the additional water Saturated Surface Dry (SSD) provides internal curing in extending the cement hydration process, thus providing splitting tensile strength at a later age.

Table 8. Recapitulation of split tensile strength test results

Wet Wipes Content	Curing Age (Day)		
	7	14	28
0%	2,435	3,247	3,390
0,15%	2,228	3,008	3,374
0,20%	1,862	2,435	3,676
0,25%	2,387	2,722	3,485

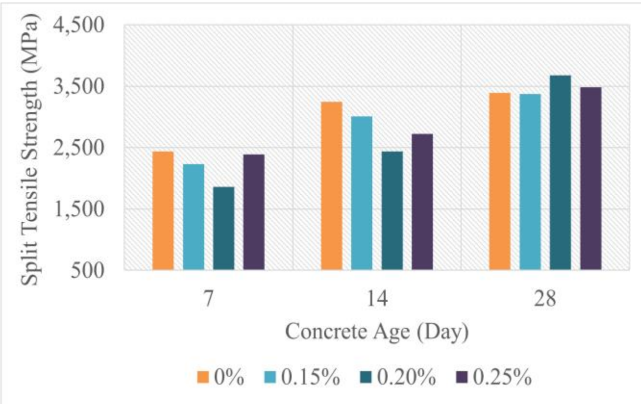

Fig. 5 Graph of split tensile strength test results at ages 7, 14, and 28 days

The addition of wet wipes fibers has an effect on the development of the splitting tensile strength of concrete. Although at an early age, there is a decrease compared to normal concrete, at 28 days, some variations actually exceed the strength of normal concrete, indicating the potential of using wet wipes fibers to improve the long-term performance of concrete.

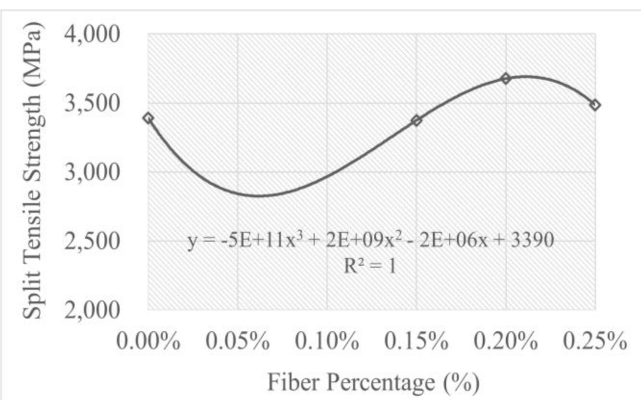

Fig. 6 Polynomial graph of the tensile strength test rate at 28 days

The results of the regression analysis (Figure 6) indicate an optimum value of 3.691 MPa with a content of 0.211%. Meanwhile, the lowest value of 1.862 MPa with a content of 0.20% at the age of 7 days indicates a negative effect caused by air entrapment at the initial age of concrete hardening. The addition of excessive fiber has the potential to damage the cement matrix bond, as seen from the test results, where the content of 0.25% experienced a decrease in split tensile strength below the content of 0.20%.

Table 9. Anova two factors with replication of split tensile strength

Factor	F	P-value	F crit
Curing age	196.132	6.84068E-10	3.885
Tissue content	8.452	0.002741827	3.490
Interaction	8.902	0.000758397	2.996

Based on the results of the ANOVA analysis (Table 9), it indicates that all factors (age, wet wipes, and their interaction) have a very significant influence on concrete with a P-value < 0.05. This indicates that the addition of wet wipe fibers affects the split tensile strength.

3.4. Absorption

The absorption of wet wipe fiber additions shown in the data shows varying values (Table 10). Normal concrete with an absorption value of 5.03% was used as a reference. The addition of fiber at a concentration of 0.15% (4.19% absorption) and 0.20% (3.77% absorption) decreased, respectively (Figure 7). This indicates that the mixture with the addition of fiber can fill the concrete pores and increase the concrete density, making it more resilient to water penetration. This statement is in line with the results of compressive and split tensile strength tests, which at a concentration of 0.20% gave stable results. The 0.25% concentration showed a sharp increase in absorption of 6.40%, the highest absorption compared to other variations. This increase indicates that the addition of too much fiber increases the concrete's ability to absorb water due to uneven fiber distribution, which ultimately creates additional voids. This phenomenon is related to the decrease in compressive and split tensile strength performance at a concentration of 0.25%.

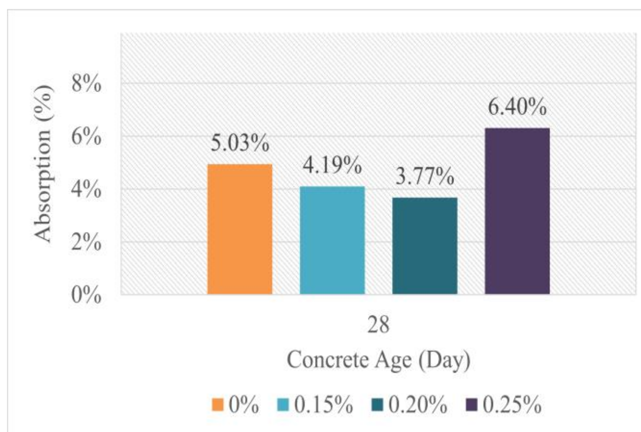

Fig. 7 Absorption test results graph for ages 7, 14, and 28 days

Table 10. Summary of concrete absorption test results

Wet Wipes Content	Curing Age (Day)
	28
0%	5,03%
0,15%	4,19%
0,20%	3,77%
0,25%	6,40%

The lowest water absorption (Figure 8) of 3.77% with a variation of 0.20% addition is categorized as the optimum value (minimum absorption). This indicates that the fiber helps the distribution of concrete and retains the right amount of water to support the hydration process, thereby increasing the concrete's density.

Conversely, the optimum water absorption (maximum absorption) of 6.70% with a content of 0.25% indicates that adding too much fiber can have a negative effect in the form of fiber agglomeration, which results in air trapping in the concrete.

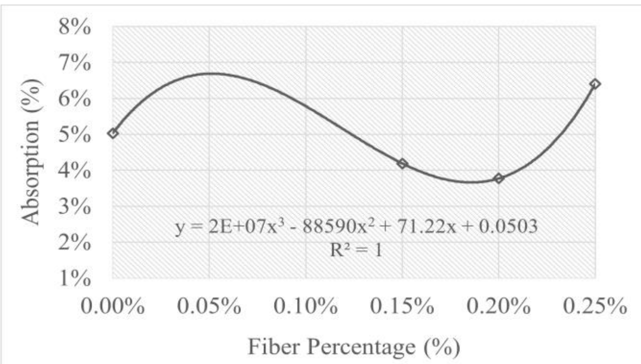

Fig. 8 Polynomial graph of optimum content of absorption test results at 28 days of age

Based on the results of the ANOVA analysis without replication in the absorption test, the P-value < 0.05 and F > F crit indicates a highly significant effect (F = 35.854 > F crit = 9.276; P-value = 0.0075). This indicates that the addition of wet tissue waste can provide benefits to the internal curing process and restore the microstructure of the concrete.

Based on the test results, it was concluded that the 0.20% variation was the most optimal absorption value compared to other additional variations. Technically, absorption refers to the porosity and density of concrete. A low porosity value indicates that the concrete has minimal pores and good density, thus minimizing the absorption of chemical solutions such as chlorides, acids, and sulfates that can damage concrete and shorten its lifespan. This indicates that concrete with low water absorption has a longer lifespan.

3.5. Cross-Sections

Cross-sectional observations were made to determine the distribution pattern of wet wipes in the concrete. The results of the concrete cross-section were documented and visually observed, showing the distribution of wet wipe fibers as shown in Figures 9, 10, and 11. At a variation of 0.15%, the fiber distribution was heterogeneous, the fiber distribution was still sparse and uneven. The fibers tended to be concentrated only at a few points, indicating that the fibers had not been distributed thoroughly. This phenomenon can be observed in Figure 9.

At the 0.20% variation, the fiber distribution appears more even compared to the 0.15% variation. The fibers begin to spread evenly across almost the entire cross-section with good distribution or homogeneity, although there are still areas with higher fiber density than other areas. This indicates a balance between the number of fibers and the ability of fiber distribution in concrete. The distribution pattern of the 0.20% variation can be seen in Figure 10. Meanwhile, at the 0.25% variation, the fibers appear more numerous and tend to be widely distributed throughout the concrete cross-section. However, fiber clumping occurs due to the large number and accumulation in several points. This can affect the homogeneity of the mixture, creating potential voids around the fiber clumps, as can be observed in Figure 11.

Observations of concrete cross-sections that have been carried out show that fiber with a variation of 0.20% is the most effective fiber proportion, supported by the results of compressive strength, tensile strength, and absorption tests, which have increased.

3.6. Coefficient of Variation (CV)

There are 56 valid concrete samples analyzed after excluding samples that have a Coefficient of Variation (CV) value below 15% with each of the 3 initial replications of four concrete variations, namely variations of 0%, 0.15%, 0.20% and 0.25%. The reliability of concrete with a CV value exceeding 15% requires correction and validity, resulting in a final elimination of 56 concrete samples with an n value of 2 samples for each variation. For each replication that shows output outside the reasonable or deviant limits, it is eliminated from the initial analysis results to ensure valid results. The eliminated samples are in accordance with general quality control guidelines in terms of concrete testing, with the highest reliability value being 0.19% (in the compressive strength and absorption test) and the largest 14.34% (in the compressive strength), which can be seen in Table 11.

Table 11. Coefficient of variation

Type of Testing	CV_{min} (%)	CV_{max} (%)
Compressive Strength	0,19	14,34
Split Tensile Strength	0,63	6,45
Absorption	0,19	6,34

3.7. Life Cycle Assessment (LCA)

This analysis was conducted qualitatively within the cradle-to-gate framework, focusing on reducing raw material consumption and reducing waste disposal. Life cycle analysis is relevant to circular economy principles. This analysis is supported by split tensile strength and durability test results, which demonstrate improved performance compared to conventional concrete. The life cycle assessment of wet wipe fibers utilization is outlined in Table 12 with modules A1-B1-B4-C4. Stage A1 highlights the use of wet wipe fibers as a new fiber. Stages B1 and B4 focus on the use of concrete during its service life and its sustainability for its service life, while stage C4 highlights the management of wet wipes waste that should be discarded but can be reused.

Because the experiments were conducted only on a laboratory scale, the LCA focused on simple stages, including utilization, use, and end-of-life. Therefore, utilizing wet wipes waste is necessary to validate large-scale production.

Table 12. Lifecycle stages of concrete with additional wet wipe fibers

Code	Life Cycle Stage	Relevance
A1	Raw Material Supply	Utilization of waste from wet wipe fibers can minimize embodied energy
B1	Use Stage	No emissions are released during the service life of the concrete
B4	Replacement	Good durability provides a longer concrete life span
C4	Disposal	Reduced waste dumped in landfills

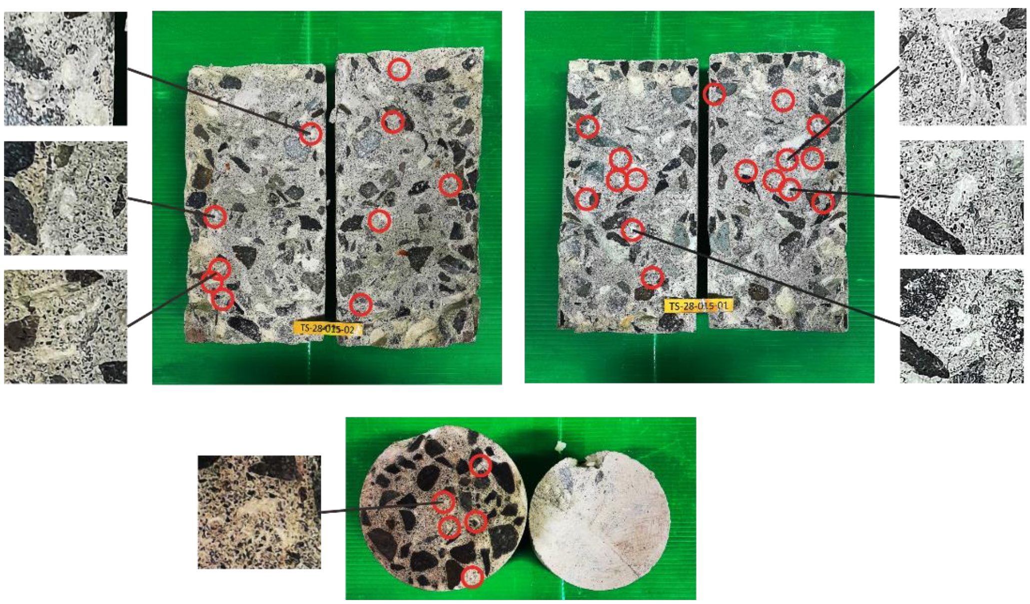

Fig. 9 Longitudinal cross-section and cross-section variation 0.15%

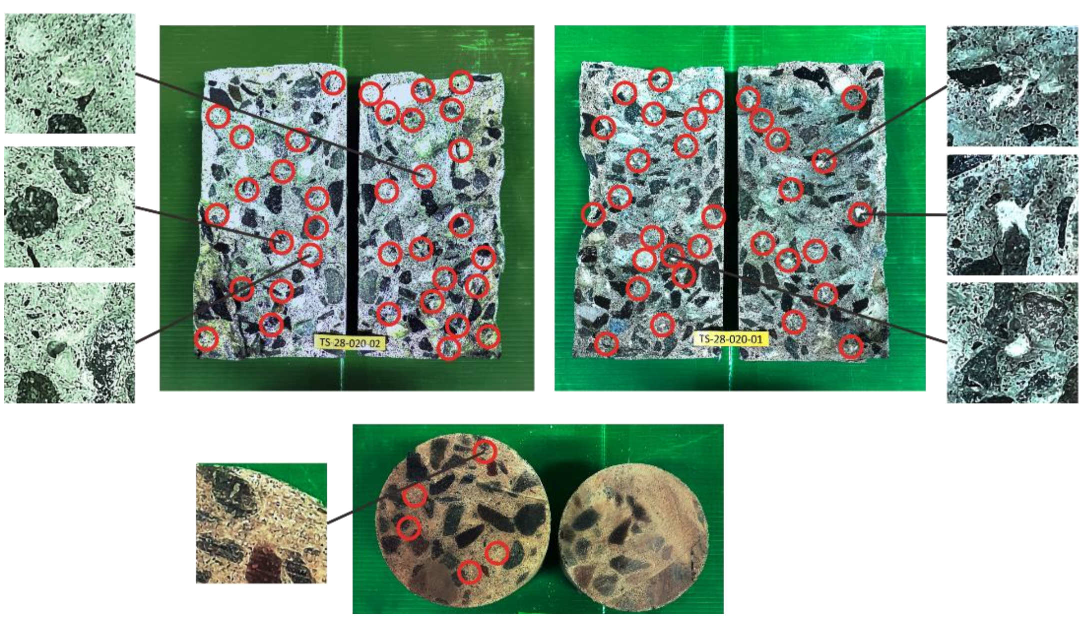

Fig. 10 Longitudinal cross-section and cross-section variation 0.20%

Fig. 11 Longitudinal cross-section and cross-section variation 0.25%

3.8. Discussion

Based on the experiments that have been conducted, wet wipe waste fibers influence concrete performance. At a variation of 0.20%, specifically, this content provides optimal results, showing compressive strength equivalent to control concrete, optimal fiber tensile strength, and superior absorption. The increase in slump value also shows the ability of fiber to play an important role in the internal curing process, so that this mechanism increases hydration and good matrix compaction at an advanced age. This results in high compressive and tensile strength and reduces water absorption. On the other hand, the addition of 0.15% and 0.25% fiber decreased performance, where low or excessive fiber grouping caused the bond to weaken and create additional voids that reduced compressive strength, increased porosity, and absorption. This finding is consistent with the results of studies that show the optimal fiber brick threshold value, which, if exceeded, causes a decrease in concrete performance.

The use of wet wipes waste as a fiber additive addresses both technical and environmental issues, demonstrating that processed waste can provide structural benefits while contributing to sustainability. Further research is recommended to explore fiber processing methods at optimum dosages, durability in aggressive environments, concrete microstructure, and the potential for industrial-scale waste utilization and environmental concerns.

Based on the results and discussion, the utilization of wet wipe fiber waste has potential in technical, economic, and environmental aspects. The use of additives paves the way to minimize concrete production costs by replacing some of the more difficult-to-find fiber additives, but it can also produce environmentally friendly concrete. This discovery provides opportunities for processing semi-structural and non-structural concrete oriented towards energy efficiency. Essentially, the integration of waste into concrete is categorized as a circular economy, based on the principle of managing and reusing waste materials.

One relevant case study on waste utilization in concrete involves the use of fly ash. Fly ash is now widely used in mass production due to its abundant availability. Research on fly ash has shown benefits in concrete strength, reduced material costs, and environmental benefits, including reduced CO_2 emissions [24].

4. Conclusion

The addition of wet wipe fibers has a significant impact on the compressive strength, splitting tensile strength, and absorption, which affect the mechanical performance and durability of concrete. The results of the compressive strength of concrete up to the age of 28 days with variations in the addition of wet wipe fibers of 0% (normal), 0.15%, 0.20%, and 0.25% are 30,000 MPa, 25,287 MPa, 30,000 MPa, and 27,291 MPa, respectively. The results of the splitting tensile strength at a percentage of 0% (normal), 0.15%, 0.20%, and 0.25% are 3,390 MPa, 3,374 MPa, 3,676 MPa, and 3,485 MPa, respectively. In comparison, the durability was found to be 5.03%, 4.19%, 3.77%, and 6.40%.

Based on the results of the regression analysis, it can be determined that the optimum value for split tensile strength can be achieved by adding a percentage of wet tissue fiber of 0.211% with a split tensile strength of 3.691 MPa. Meanwhile, the optimum value for durability (absorption) can be achieved by adding a percentage of wet wipe fibers of 0.20% with the lowest absorption value of 3.77%. Therefore, further research is recommended for testing at variations of around 0.20% to obtain more accurate results. Besides that, the results of the ANOVA analysis for each test variation with a P-value < 0.05 indicate a strong significance in the results of the compressive strength, split tensile strength, and absorption tests. Overall, the fiber content of 0.20% is the critical point that provides the best performance with a combination of optimum tensile strength, compressive strength that is still equivalent to the control concrete, and minimum absorption.

The life cycle assessment analysis of the addition of wet wipe waste with the LCA A1-B1-B4-C4 module not only focuses on concrete performance but also impacts the environment in line with the principles of a circular economy.

Some recommendations for further research include optimizing the mixing method to minimize uneven fiber distribution, conducting tests with concrete service ages of 56, 90 to 180 days to see the effectiveness of fiber on concrete in a longer period of time, flexural strength testing, elastic modulus and durability such as the Rapid Chloride Ion Penetration Test (RCP), permeability, carbonation tests and other durability tests are required. In addition, microstructural analysis with a Scanning Electron Microscope (SEM) is recommended to reconfirm the distribution of fibers and their interaction with concrete.

Funding Statement

This research was conducted without any financial support from the government, commercial, or nonprofit organizations.

Acknowledgments

The author would like to thank the laboratory staff and colleagues who provided technical support during material preparation and mixing. The author also extends his deepest appreciation to the Department of Architectural Engineering for granting access to the structural laboratory facilities.

References

[1] Xiou Ge et al., "Accelerated Discovery of Sustainable Building Materials," *arXiv preprint*, pp. 1-6, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[2] Abhijit Warudkar, and S. Elavenil, "Evaluation of the Relationship between Strength, Quality Grade, Microstructure and Abrasion of Concrete," *Materials Research Express*, vol. 8, pp. 1-10, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Indra Kumar Pandey et al., "Impact of Curing on Mechanical Properties of Concrete-Environmental Approach," *Journal of Environmental Nanotechnology*, vol. 7, no. 4, pp. 60-64, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[4] M. Tumpu, Irianto, and H. Parung "The Effect of Curing Methods on Compressive Strength of Concrete," *IOP Conference Series: Earth and Environmental Science: The 3rd International Conference on Global Issue for Infrastructure, Environment, and Socio-Economic Development*, Makassar, South Sulawesi Province, Indonesia, vol. 921, pp. 1-10, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[5] Marta Słowik, and Amanda Akram, "Length Effect at Testing Splitting Tensile Strength of Concrete," *Materials*, vol. 15, no. 1, pp. 1-14, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[6] Ali Jaber, Iqbal Gorgis, and Maan Hassan, "Relationship between Splitting Tensile and Compressive Strengths for Self-Compacting Concrete Containing Nano- and Micro Silica," *MATEC Web of Conferences*, vol. 162, pp. 1-8, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[7] ACI 224R-01, "*Control of Cracking in Concrete Structures*," American Concrete Institude, pp. 1-10, 2021. [Google Scholar] [Publisher Link]

[8] Adam M. Neville, *Properties of Concrete*, Pearson Education Limited, pp. 1-846, 2011. [Google Scholar] [Publisher Link]

[9] Ado Maaruf, and Nuruddeen Muhammad, Review of the Methods Used in Concrete Durability Assessment, International Journal of Engineering & Science Research, pp. 264-269, 2022. [Online]. Available: https://www.researchgate.net/publication/358281615

[10] Zhu Yuan, and Yanmin Jia, "Experimental Study on the Mechanical Properties, Water Absorption, and Fiber Degradation of Naturally Aged Glass Fiber and Polypropylene Fiber-Reinforced Concrete," *Materials*, vol. 15, no. 11, pp. 1-20, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[11] Ghewa Gabriel et al., "Investigation of Water Absorption for Concrete Using Supplementary Materials," *IPTEK The Journal for Technology and Science*, vol. 31, no. 3, pp. 309-317, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[12] Iliana Papamichael et al., "Construction and Demolition Waste Framework of Circular Economy: A Mini Review," *Waste Management & Research: The Journal for a Sustainable Circular Economy*, vol. 41, no. 12, pp. 1728-1740, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[13] C. Meyer, "The Greening of the Concrete Industry," *Cement and Concrete Composites*, vol. 31, no. 8, pp. 601-605, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[14] Serkan Durukan, and Fatih Karadagli, "Experimental Data for Physical Characteristics, Fiber Compositions, and Tensile Properties of Nonwoven Wipes and Toilet Papers," *Data in Brief*, vol. 28, pp. 1-18, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[15] Suvash Chandra Paul, Gideon P.A.G. van Zijl, and Branko Šavija, "Effect of Fibers on Durability of Concrete," *Materials*, vol. 13, no. 20, pp. 1-26, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] Baby Wipes Market Share in Indonesia: Mothers' Habits & Preferences, Sigma Research Indonesia, 2020. [Online]. Available: https://sigmaresearch.co.id/7028-2/

[17] Ahmed Abd El Aal et al., "Advances on Concrete Strength Properties after Adding Polypropylene Fibers from Health Personal Protective Equipment (PPE) of COVID-19: Implication on Waste Management and Sustainable Environment," *Physics and Chemistry of the Earth, Parts A/B/C*, vol. 128, pp. 1-12, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Shannon Kilmartin-Lynch et al., "Preliminary Evaluation of the Feasibility of Using Polypropylene Fibres from COVID-19 Single-Use Face Masks to Improve the Mechanical Properties of Concrete," *Journal of Cleaner Production*, vol. 296, pp. 1-8, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[19] Sifatullah Bahij et al., "Effect of Non-Woven Polyethylene Terephthalate (PET) Tissue on Fresh and Hardened Properties of Concrete," *Materials*, vol. 15, no. 24, pp. 1-30, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[20] Mohanad S. Eid, and Hosam M. Saleh, *Characterizations of Cement and Modern Sustainable Concrete Incorporating Different Waste Additives*, Sustainability of Concrete with Synthetic and Recycled Aggregates, pp. 1-15, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[21] ACI 214R-11, *Guide to Evaluation of Strength Test Results of Concrete*, American Concrete Institute, pp. 1-16, 2011. [Google Scholar] [Publisher Link]

[22] EN 15804+A2, "*Sustainability of construction Works - Environmental Product Declarations- Core Rules for the Product Category of Construction Products*," Standards Technical Report, 2019. [Google Scholar] [Publisher Link]

[23] Rachmat Purwono et al., *Procedures for Calculating Concrete Structures for Buildings (SNI 03-2847-2002) Complete with Explanations (S-2002)*, Indonesian National Standard (SNI), Surabaya: ITS Press, pp. 1-402, 2009. [Google Scholar] [Publisher Link]

[24] Ratih Permatasari, Ahyahudin Sodri, and Haruki A. Gustina, "Utilization of Fly Ash Waste in the Cement Industry and its Environmental Impact: A Review," *Journal of Science Education Research*, vol. 9, no. 9, pp. 569-579, 2023. [CrossRef] [Google Scholar] [Publisher Link]