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ANALYSIS OF THE EFFECT OF USING COVID-19 MEDICAL MASK WASTE WITH POLYPROPYLENE ON THE COMPRESSIVE STRENGTH AND SPLIT TENSILE STRENGTH OF HIGH-PERFORMANCE CONCRETE

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The coronavirus causing the Covid-19 pandemic has been experienced by us since 2020, which has led to an increase in the use of disposable medical masks in Indonesia and even worldwide. Polypropylene is a thermoplastic polymer used as the main ingredient in medical masks that takes more than 25 years to decompose in landfills. This research offers an innovative way to use medical mask waste in high-performance concrete. The resulting medical mask waste is subjected to a sterilization process and cut into fibers to analyze the effect of its addition on the compressive strength and splitting tensile strength of high-performance concrete. The research began with testing the physical and mechanical properties of the materials, designing a concrete mix using the absolute volume method, and taking samples for compression and splitting tests. The variation in the ratio of water-cement and pozzolanic materials w (c+p) is 0.32. As a result, the compressive strength of concrete increased with a fiber size of 5×0.5 cm and 2×0.5 cm. An increase is up to 7 % with an optimum value of 72.37 MPa with a fiber size of 2×0.5 cm and a content of 0.15 %. However, there was a decrease in the compressive strength with a 5×1 cm mask fiber size. The overall split tensile strength value of all variations in waste fiber size and content increased with an optimum value of 7.29 MPa at 0.20 % fiber content with a fiber size of 5×0.5 cm. This indicates that polypropylene fibers from medical mask waste have a positive effect on high-performance concrete, namely improve the properties of concrete with a low tensile strength, which is expected to inhibit the propagation and reduce the size of cracks in reinforced concrete structures

Keywords: high-performance concrete, medical mask waste, polypropylene fiber, compressive strength, split tensile strength

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1. Introduction

Coronavirus has caused Covid-19 since 2020. It is increasing global disposable mask use. The world [1] reports 159.490.374 verified Covid-19 cases as of November 5, 2021. In offices, public areas, and worship institutions, masks are required. Washable masks can be reused. Once-used masks become wasteful mask garbage. Medical masks, N95 or KN95 masks, cannot store bacteria or viruses on the surface. Therefore [2], they can still transmit the virus if handled poorly. By law, medical masks used outside hospitals are considered household garbage. Mask trash can harm nature if not appropriately discarded.

Most disposable medical masks are polypropylene [3]. Polypropylene, the principal plastic used in disposable masks, takes more than 25 years to decompose. As a result, when disposable masks wind up in our waterways, they break into microscopic plastic bits called "microplastics" [4]. The global epidemic has affected our economy and will continue to do so when it ends.

Plastic fibers have long been utilized in concrete since they are more durable than steel. Polypropylene (PP) fibers are used widely in the concrete industry due to their tensile strength, Young's modulus, ease of manufacture, and good alkali resistance. Polypropylene-fiber-reinforced concrete was tested [5]. The concrete mix contains 0 % to 0.3 % polye propylene (based on the volume of concrete). Adding 0.30 % polypropylene fiber to concrete decreased the compressive strength by 10 %. Even though the compressive strength decreased, the splitting strength increased by 39 %. The work [6] performed a similar investigation on fiber-reinforced concrete and discovered that cellulose fiber (CTF) at 1.5 kg/m^3 increased the concrete's compressive strength by 12 %, whereas polyvinyl alcohol fiber (PF) at 4.0 kg/m^3 decreased it by 35 %. CTF's split tensile strength declined by 23 %, PF's by 55 %, and polyolefin fibers' at 2.0 kg/m^3. Waste plastic fibers enhanced the compressive strength of all mixes relative to the control. The compressive strength was 46–56 MPa, 51–68 MPa, and 53–77 MPa at 7, 14, and 28 days. In that study, WPF strengthened all blend designs' flexural strength. Several experiments [7] have been done to evaluate how Covid-19 mask fibers affect concrete's mechanical qualities. Compressive strength, tensile strength, modulus of elasticity, and ultrasonic testing speed to test

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the overall quality of concrete with a 2 cm long and 0.5 cm broad mask at 0 % (control), 0.10 %, 0.15 %, 0.20 %, and 0.25 % of the concrete volume. New medical masks were not wasted in this investigation. Since disposable medical masks are widespread, concrete strength and quality have grown. After 0.20 %, the strength starts to decline. The influence of polypropylene-based Covid-19 medical mask waste on concrete strength is relevant and should be researched in a concrete building.

2. Literature review and problem statement

High-performance concrete does not contain recycled materials, while in this study it contains recycled materials, namely Covid-19 mask waste so it is categorized as high-performance concrete, which is defined as concrete that has high workability, high strength, and high durability. High-performance concrete (HPC) is a very complex material. SNI that regulate high-performance concrete that are currently in effect are SNI 7656:2012 and SNI 03-6468-2000. As it is a relatively new material, research data supporting the development of high-performance concrete is also increasing. However, [8] additional research is still needed to fully exploit its advantages and ensure the ability of high-performance concrete. One of the basic components for producing high-performance concrete is portland cement type I (Ordinary Portland Cement, OPC). In fact, the cement circulating in the Indonesian market is a type of Portland Pozzolan Cement (PPC) or composite cement (PCC). In terms of mechanical properties, the ability of high-performance concrete (HPC) to withstand tensile and shear stresses is very small, which is in the range of 8–15 % of compressive strength. High-performance concrete [9] can be divided into five classes. The range of rising strength class of high-performance concrete is 25 MPa. Class I is high-performance concrete with a compressive strength between 50 and 75 MPa, class II between 75 and 100 MPa, class III between 100 and 125 MPa, class IV between 125 and 150 MPa, and class V above 150 MPa. ACI 363R-92 states that the lower limit of the compressive strength of high-performance concrete is chosen to be 41 MPa. According to ACI Committee 363, to increase the strength of concrete, several basic concepts need to be followed, including:

1. Increased cement paste strength, which can be usually obtained by:

a) reducing the porosity of the paste, reducing the water-to-cement ratio and or using a superplasticizer;

b) using mineral admixtures, such as silica fume and fly ash.

2. Selection of good aggregate quality.

3. Increasing the bond strength between the cement paste and aggregate, which mainly depends on the selection of the properties and shape of the aggregate. High-quality concrete is a concrete mixture that can produce the basic criteria of the mixture, namely compressive strength, durability, permeability and workability. To get this, it is necessary to have a principle of how to use additional materials such as superplasticizers, silica fume or fly ash. To achieve high-quality concrete, the additional mixture must be taken optimally, because excess additives will result in negative properties for the concrete mixture. According to previous studies, fly ash mixtures range from 10–35 %, silica fume mixtures range from 10–15 % and the use of superplasticizers is in accordance with brochures and manufacturers. A good high-performance concrete mix must meet the following factors:

1. High strength, so that when combined with reinforcement steel having high compressive strength it can be used for heavy structures.

2. Durability, namely resistance to corrosion/decomposition under environmental conditions.

3. Ease of workability, this property is a measure of ease of stirring, transporting, pouring and compaction.

The study [10] showed that the use of plastic in concrete in the construction industry has benefits and sustainability when compared to steel reinforcement. The work [11] shows the results of research that polypropylene (PP) fiber has been widely used in the concrete industry because it has mechanical properties, namely tensile strength and Young's modulus, as well as ease of production and high alkali resistance. The experiment [11] analyzed polypropylene fiber-reinforced concrete. A varying volume of polypropylene is introduced into the concrete mix between 0 % and 0.3 % (based on concrete volume), with the compressive strength showing a slight decrease during the test period with the largest decrease of 10 % with the addition of 0.30 % polypropylene fiber to the volume of concrete. Although the compressive strength shows a decrease, the splitting strength had a remarkable increase of 39 % when combined with polypropylene fibers with the inclusion of 0.1 % fiber to the volume of concrete. But this experiment [12] has not clearly conveyed the optimum value of strength to increase the mechanical properties of concrete.

The paper [12] investigated the potential benefits of using recycled high-density polyethylene (HDPE) fibers in structural concrete. The research evaluates the mechanical properties of concrete through a series of different specimens. In addition to the control mix, two fiber diameters were tested with HDPE including volume at 0.40 %, 0.75 % and 1.25 % for each fiber diameter. They noted that the compressive strength and Young's modulus were not affected by the addition of HDPE fibers but the flexural and tensile strengths increased by approximately 3 % and 14 % when HDPE fibers were introduced into the concrete mix by 0.40 % and 1.25 %, respectively. But in this study [12], the age of concrete mortar has not been presented, which is the most significant for increasing the flexural and tensile strength of concrete, so it needs to be studied for further research.

In the next study [13], an analysis of polypropylene-reinforced concrete with 0 to 0.3 % amounts of polypropylene was carried out. The compressive strength decreased by 10 % with 0.30 % polypropylene fibers per volume of cone crete. With polypropylene fibers, the compressive strength decreases while the split tensile strength increases. But the study [13] has not clearly conveyed the optimum value of strength for an increase and decrease in the mechanical properties of concrete.

The work [7] studied the impact of mask fibers on concrete's mechanical characteristics. Mask variations with a 2 cm length and 0.5 cm width with a 0 % (control), 0.10 %, 0.15 %, 0.20 %, and 0.25 % concrete volume were investigate ed. The results revealed an increase in concrete strength and quality. The trend starts to weaken if the percentage is more than 0.20 %. But in this study [7], the water-cement factor used and the quality of the planned concrete have not been conveyed, so this raises big questions for the reader. And the new medical masks used are not mask waste.

In the studies that have been done, the optimum value of strength to increase the mechanical properties of high-performance concrete with polypropylene fiber from medical mask waste has not been conveyed so this needs to be re-examined further. There has been much research on the use of plastic waste in concrete, but very few studies have been done on the use of waste Covid-19 medical masks with polypropylene fiber in high-performance concrete. This study looks at the utilization of Covid-19 medical mask waste in high-performance concrete. The effect of varying levels of polypropylene fiber from Covid-19 medical masks on the compressive strength of concrete and split tensile strength of high-performance concrete will be examined in this study.

3. The aim and objectives of the study

The aim of the study is to analyze the effect of adding polypropylene fiber from Covid-19 mask waste on the strength of high-performance concrete.

To achieve the aim, the following objectives are accomplished:

– to investigate the effect of adding polypropylene fiber from Covid-19 mask waste on the compressive strength;

– to investigate the effect of adding polypropylene fiber from Covid-19 mask waste on the split tensile strength.

4. Materials and methods

This study aims to recycle and repurpose discarded Covid-19 medical masks in high-performance concrete. This reduces pandemic waste. The effect of adding mask waste fiber on the compressive strength and tensile strength of high-performance concrete is reviewed. The research process from start to finish can be explained by the flowchart in Fig. 1.

Fig. 1 explains how the research process started until completed.

This investigation used Portland Cement Composite (PCC) product from Cement Gresik, Indonesia, Lumajang sand, Pasuruan gravel, water, silica fume, Sika® Visco-Crete®-3115 N superplasticizer, and Covid-19 mask waste polypropylene fiber. The test comprises sieve analysis, specific gravity, aggregate moisture content, water absorption, and a gravel wear test utilizing the Los Angeles abrasion test. Table 1 shows the composition of a high-performance concrete mix with $w/(c+p)$=0.32, 10 % silica fume, and 90 % cement.

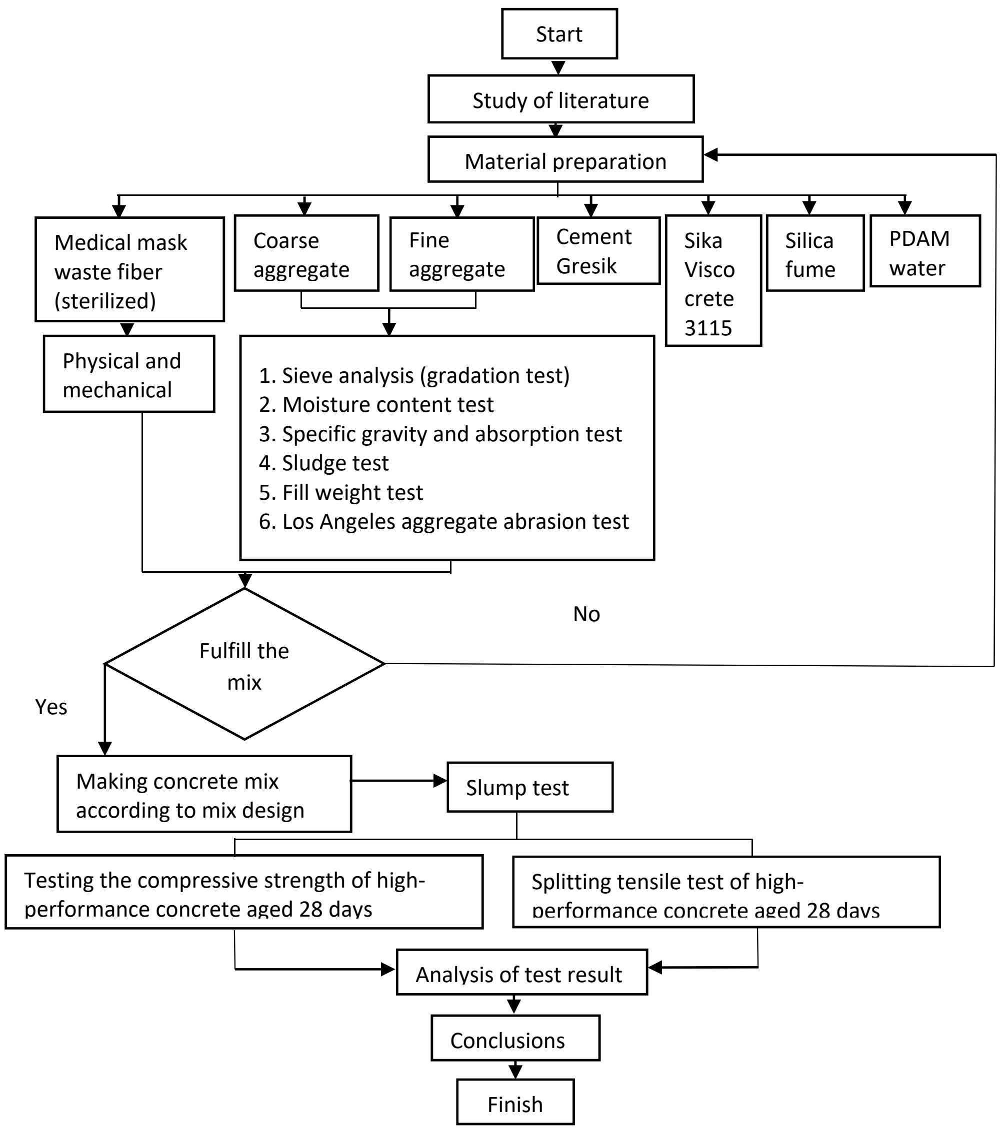

Fig. 1. Research flowchart

Table 1

Composition of the concrete mix

Material	Unit	0.0 %	0.15 %	0.20 %	0.25 %	0.30 %
Water	l	97.22	97.22	97.22	97.22	97.22
Cement	kg	393.75	393.75	393.75	393.75	393.75
Silica fume	kg	43.75	43.75	43.75	43.75	43.75
Course aggregate	kg	1088.33	1088.33	1088.33	1088.33	1088.33
Fine aggregate	kg	675.15	675.15	675.15	675.15	675.15
Superplasticizer	l	9.04	9.04	9.04	9.04	9.04
Medical mask waste	g	0	136.5	182	227.5	273

Source: Mix design sheet [9]

Table 1 describes the composition of high-performance concrete mixtures according to their constituent materials and each weight needed in this study. Compiled referring to the Mix design sheet prepared by [9], based on ACI 211.1-91, 1991 [14] so that a concrete mix is obtained for each m^3.

To achieve high-quality concrete, it is necessary to have good quality and standard concrete constituent materials. The results of the fine aggregate quality test of Lumajang sand (Table 2) and the coarse aggregate quality test of Pasuruan mountain crushed stone (Table 3) are presented.

Table 2

Fine aggregate quality test results

Properties of fine aggregate	Unit	Test result	Standard
Fineness modulus	–	2.87	2.0–4.5
Humidity	%	3.89	1–5
Water absorption	%	0.38	<2
Specific gravity	–	2.74	2.5–3.0
Finer material less than 75 µm	%	0	0

Table 2 shows the results of testing the fine aggregate of Lumajang sand for fineness modulus based on ASTM C 136-76, SSD specific gravity based on ASTM C 556-72, water absorption based on ASTM C 128, and water content based on ASTM C 136-78, all meet the standard requirements.

Table 3

Coarse aggregate quality test results

Properties of course aggregate	Unit	Test result	Standard
Fineness modulus	–	7.91	5.0–8.0
Humidity	%	3.28	1–5
Water absorption	%	2.04	1–5
Specific gravity	–	2.82	2.5–3.0
Los Angeles abrasion value	%	16.35	<40

Table 3 shows the results of coarse aggregate testing of Pasuruan mountain crushed stone with a max diameter of 19 mm, for fineness modulus based on ASTM C 136-76, SSD specific gravity based on ASTM C 556-72, water absorption based on ASTM C 128, and water content based on ASTM C 136-78. All meet the standard requirements.

Medical mask trash was sanitized, ear straps and inner nose wire were removed, and then chopped into small rectangular pieces measuring 2×0.5 cm, 5×0.5 cm, 5×1 cm, with 0 % (control mixture), 0.15 %, 0.20 %, 0.25 %, and 0.30 % mask-concrete volume variations.

Fig. 2 shows Covid-19 polypropylene medical mask waste, which has been cut into fibers according to the size needed in the study.

Fig. 2. Fiber from the waste of Covid-19 medical masks

The physical and mechanical properties of Covid-19 medical masks have been researched and used as secondary data in this study presented in Table 4.

Table 4

Physical and mechanical properties of medical masks

Physical properties	Value	Standard
Specific gravity	0.91	ASTM D792-20 (2020)
Melting point (°C)	160	ASTM D7138-16 (2016)
Water absorption 24 h (%)	8.9	ASTM D570-98 (2018)
Tensile strength (MPa)	4.25	ASTM D638-14 (2014)
Tensile strength at break (MPa)	3.97	ASTM D638-14 (2014)
Elongation at break (%)	118.9	ASTM D638-14 (2014)
Rupture force (N)	19.46	ASTM D638-14 (2014)
Aspect ratio	24	–

Source: Kilmartin-Lynch 2021 [7]

Table 4 shows the results of testing the physical and mechanical properties of Covid-19 medical masks based on the ASTM D638-14 standard.

The concrete is poured using a 120 L mixer with a maximum output volume of 90 L. The high-performance concrete mixing process begins by adding sand and gravel to the mixer for approximately 3–5 minutes. Then cement, silica fume and Covid-19 medical mask waste fibers are put into the mixer and stirred for 3–5 minutes. Next, the superplasticizer mixed with water is added. The concrete mixture is stirred for approximately 3–5 minutes until the concrete mixture looks wet and the mixture is uniform, then a fresh concrete viscosity test is carried out with a slump test. Further, the concrete mixture is poured into a 15×30 cm mold. After one day, the mold with the test object can be opened and then allowed to stand for 28 days so that the hydration process occurs. Then the compressive strength and split tensile strength are tested.

5. Results of research on the effect of polypropylene fiber from Covid-19 mask waste on the strength of high-performance concrete

5. 1. Compressive strength test

The study's results on the effect of variations in the fiber content of Covid-19 mask waste on the compressive strength of high-performance concrete aged 28 days are shown in Fig. 3. These results are the average of 10 test objects in each treatment.

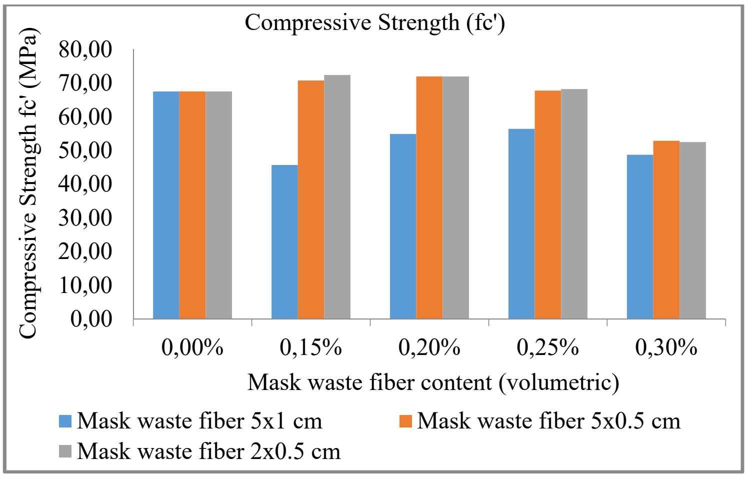

Fig. 3. Compressive strength of high-performance concrete from Covid-19 mask waste polypropylene fiber

Fig. 3 shows the results of the compressive strength of a cylindrical test object (15/30 cm) in all treatments for 28 days, concrete mix with $w/(c+p)=0.32$. The control compressive strength value (without waste fiber) is 67.51 MPa.

With mask waste fiber dimensions (5×1) cm, the optimum compressive strength is 56.40 MPa at 0.25 % fiber content, decreased by 16 %. With fiber dimensions (5×0.5) cm, the optimum compressive strength value is 71.94 MPa at 0.20 % fiber content, an increase of 6.16 %. With fiber dimensions (2×0.5) cm, the optimum compressive strength value is 72.37 MPa at 0.15 % fiber content, an increase of 6.72 %.

5. 2. Split tensile strength test

Fig. 4 shows the results of research on the relationship between the fiber content of Covid-19 mask waste and the split tensile strength of high-performance concrete.

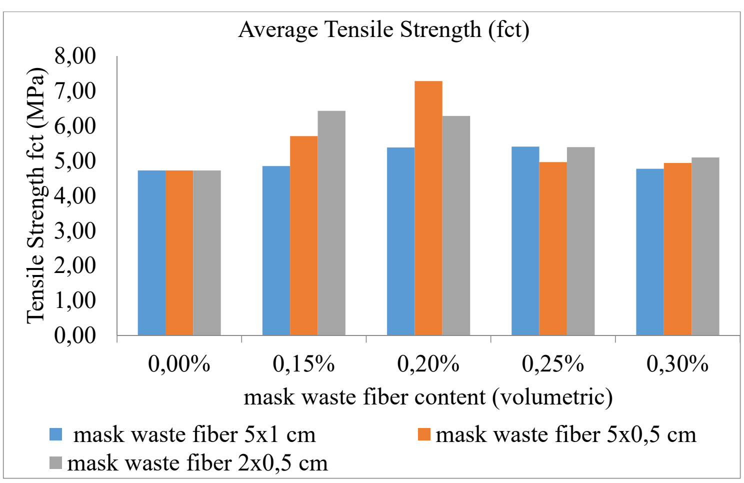

Fig. 4. Split tensile strength of high-performance concrete from Covid-19 mask waste polypropylene fiber

Fig. 4 shows the results of the split tensile strength of a cylindrical test object (15/30 cm) in all treatments for 28 days, concrete mix with $w/(c+p)=0.32$. The split tensile strength value of the control (without mask waste fiber) is 4.73 MPa. With mask waste fiber dimensions (5×1) cm, the optimum split tensile strength is 5.41 MPa at 0.20 % fiber content, an increase of 12.57 %. With fiber dimensions (5×0.5) cm, the optimum split tensile strength value of 7.29 MPa occurs at 0.20 % fiber content, an increase of 35.12 %. With fiber dimensions (2×0.5) cm, the optimum split tensile strength value is 6.43 MPa at 0.15 % fiber content, an increase of 26.44 %.

6. Discussion of the results of research on the effect of adding polypropylene fiber from the waste of Covid-19 medical masks on the strength of high-performance concrete

Fig. 3 shows the effect of adding polypropylene fiber from mask waste, causing the compressive strength of high-performance concrete with a 5×1 cm mask size to decrease (by 16–32) %, with a compressive strength value of 45.68–56.40 MPa. In contrast to the addition of mask waste fiber measuring 5×0.5 cm and 2×0.5 cm, the compressive strength value increases. The results of the compressive strength of the 5×0.5 cm mask showed an increase in fiber content by 0.15 % and 0.20 %, while it decreased slightly by 0.25 % and 0.30 %. With a size of 2×0.5 cm, the compressive strength increased by 7 % with the optimum value at 0.15 % fiber content and decreased by 0.20 %, 0.25 % and 0.30 %. However, the decrease in compressive strength of up to 0.25 % is still above the control compressive strength (without fiber). For fiber measuring 5x0.5 cm, the compressive strength value increased by 6 % from 0.15 % fiber content, the optimum was 0.20 % and slightly decreased, still above the control compressive strength of 0.25 %. From the discussion of these results, it can be concluded that the addition of Covid-19 medical mask waste fiber to high-performance concrete has a relatively small effect on increasing the compressive strength of concrete due to the density of voids and increases the binding strength of cement bonds in the concrete mix. The results of this study were confirmed by previous studies with similar results for the compressive strength of polypropylene medical mask fiber concrete. The compressive strength of the mask fiber increased by 0.10 %, 0.15 % and 0.20 % until it reached the peak, then decreased by 0.25 %. The research [5] found that adding plastic fiber increased the compressive strength until the compressive strength level was at 0.20 % plastic content and then decreased at greater fiber content. The work [15] also associated fiber cracking with an increase in the compressive strength of polypropylene fibers. The decreasing trend at 0.25 % fiber content may be due to voids and weak cement bonds.

As shown in Fig. 4, the split tensile strength of the control (without mask waste fiber) is 4.73 MPa. The addition of mask waste fiber for all fiber variations and contents in general caused an increase in split tensile strength. The split tensile strength results obtained an optimum value of 7.29 MPa at 0.20 % fiber content and 5×0.5 cm fiber size, with an increase of 35.12 % from the control tensile strength value (without the addition of medical mask waste fiber). The tensile strength increased at various mask waste fiber levels of 0.15 % and 0.20 % and decreased at the fiber content of 0.25 % and

0.30 % but still the split tensile strength increased when compared to the control split tensile strength without mask waste fiber. Improvement of concrete quality as described in the compressive strength results allows the tensile strength to increase in the same range. The split tensile strength results showed that high-performance concrete benefited from the addition of Covid-19 medical mask waste fibers. The results show a stable increase in split tensile strength for all variations in fiber size and content. This indicates that improving the quality of high-performance concrete with a low tensile strength can be improved by adding fibers from Covid-19 medical mask waste to the concrete mixture. The results of a similar study on the split tensile strength of polypropylene face mask fiber concrete are shown in [7]. The tensile strength increased to 15 % at 0.10 %, 0.15 % and 0.20 % fiber and slightly decreased at 0.25 % of the control variable. Another study [12] explained that by increasing the fiber content of PET plastics, they become denser, resulting in increased elasticity and compressive strength. The increase in split tensile strength can be attributed to the fiber content of plastic fibers, which provide all the tensile stresses, as shown in [16], where stress is transferred from the fibrous polypropylene mixture increasing the tensile strength is a characteristic of concrete. It was concluded that the addition of fiber to the concrete mix can increase the split tensile strength, changing the concrete from a brittle material to a more ductile one.

The limitation of this study is that you have to be careful in collecting Covid-19 mask waste. The sterilization process must be carried out properly as recommended by WHO for the safety of researchers and all parties involved in the research process. In this preliminary study, it has been proven from the initial hypothesis that the addition of fiber strengthens concrete against tensile strength, this also occurs with the addition of polypropylene fiber from medical mask waste to high-performance concrete. This is very beneficial for concrete to improve its weak properties against tensile strength. This research is therefore feasible as a continuation of the study in creating environmentally friendly concrete by utilizing medical mask waste fiber in an effort to repair cracks that occur in concrete because the tensile strength of concrete increases in general using Covid-19 mask waste fiber, which is slightly in accordance with the rules that apply to concrete fiber.

7. Conclusions

1. The addition of Covid-19 mask waste fibers to the concrete mix had no significant effect on increasing the compressive strength of high-performance concrete. The increase was only 7 %, for the size variations of 5×0.5 cm and 2×0.5 cm at the fiber content of 0.15 % and 0.20 %, while in general the compressive strength decreased for other fiber contents and sizes. However, the addition of Covid-19 mask waste fiber containing polypropylene can increase the energy absorption capacity (toughness) to withstand workloads and change concrete from a brittle material to a more ductile one.

2. The addition of medical mask waste fiber as a whole can increase the split tensile strength of high-performance concrete for all variations of fiber content and size. The results of the split tensile strength obtained were the optimum value of 7.29 MPa of 0.20 % with a fiber size of 5×0.5 cm, with an increase of 35.12 % from the control tensile strength value. Polypropylene fibers from medical mask waste, which were cut into small pieces, showed that fibers were proven to increase the tensile strength of concrete. This fiber can limit the number of micro-cracks in concrete, thereby increasing the overall quality of concrete, improving the properties of concrete with low tensile strength.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

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