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The Compressive Strength of Concrete with Addition of Single-Use Mask Waste Fiber

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Abstract. This research proposes investigating the effect of adding single-use face mask fiber of concrete compressive strength. The fiber was taken from the mask waste as additional material in concrete. The variation of mask fiber content in the concrete are 0%, 0,125%, 0,25%, 0,375%, 0,5%, and 0,75% from total weight of concrete. About 18 cylinder specimens with 150 mm x 300 mm were used to test the compressive strength. Concrete making and testing follow standard testing from ASTM. Specimen tested compressive strength for each variation and compared to the specimen without mask fiber (variation 0%). Test results show decreasing compressive strength aligned with the increasing additional mask fiber. Decreases of compressive strength from 0,125% to 0,75% are 9,34% to 57,23%, sequentially. Compressive strength with mask fiber 0,125% and 0,25% are 20,63 MPa and 18,74 MPa that are still qualified for structural. Meanwhile, the variations 0,375%, 0,5%, and 0,75% the compressive strength under 17 MPa that do not qualify for structural. The optimum addition of mask fiber is 0,125%, decreasing the compressive strength of 9,34% compared to the concrete without mask fiber. Crack after maximum load occurs in different conditions between normal concrete and concrete with mask fiber, which caused of the mask fiber can minimize crack opening. Small crack opening shows the mask fiber content in the concrete has improved the ductility compared to the normal concrete. With an additional 0,125% of mask fiber, it estimates that the amount of adopted mask waste in a 1m^3 concrete is 2,75 kg or about 687 pcs mask.

INTRODUCTION

The COVID-19 pandemic has lasted for two years since the beginning of 2020 and has impacted various sectors of life around the world. One of the impacts caused by the COVID-19 pandemic is the existence of a new life habit, namely using masks in daily activities (1). The increased use of masks such as single-use masks is significant because it is an obligation to implement health protocols to prevent virus transmission. Due to the massive use and single-use, another impact is increased mask waste. A preliminary survey shows that the average use of single-use masks is 2 per person in one day. Single-use masks used are medical masks, cloth masks, and other masks. The generation of mask waste due to its massive use, if not handled properly, will be contaminating the environment. This is because the primary material for single-use medical masks is polypropylene (plastic-type), and the natural decomposition process takes a very long time (2).

Several methods have been done by both the government and the private industry, including destruction by the incinerator, solidification, or physically changing them into other recycled goods (3,4). Several solidification methods have been carried out, including converting them as construction materials or other materials. There is a material known as fiber concrete in civil engineering material technology. Because the primary material of single-use masks is polypropylene, a plastic material, the mask can be used as a fiber material classified as plastic fiber for fiber concrete mixtures. Fiber concrete has been widely developed as recycled material for repair and rehabilitation, reinforcement of structural elements, and other construction industry needs (5). Concrete is one of the most widely used materials in building construction, both structural and non-structural. The constituents of concrete are cement, sand, gravel, water, and other additives (6). Additional materials mixed into concrete are carried out for specific purposes, such as improving quality, easier for work, accelerating or slowing drying, and the need for waste management or other material recycling. Several studies on fiber concrete as examined reinforced concrete with recycled fibers from rubber, steel, plastic, and wood materials (7), mechanical properties of fiber concrete in which the fibers used were natural fibers from coconut fibers and pineapple leaves (8,9), fiber

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concrete from banner waste which includes plastic fiber (10), and concrete beams with added bagu fiber (natural fiber) (11). In addition to structural concrete, other materials such as pavement materials were also studied and showed good effects (4,12). From the results of research conducted, the effect of increasing strength mostly occurs in tensile strength and ductility. In contrast, the compressive strength significantly decreased if the addition more than 2%.

Single-use masks are made of polypropylene, which belongs to the plastic fiber category. Concrete was chosen as a recycling alternative for single-use mask waste because its massive use for construction and concrete is very commonly known in the community. Concrete mask-fiber is a considerable recycling potential because of the massive amount of waste generated during the pandemic. So it is necessary to test the strength of the concrete due to the addition of mask fibers to determine the optimum level. The addition of mask fibers is limited so that it does not disturb the strength of the concrete so that it can still be used as a construction material. Mask waste that has been sorted and collected is taken for the fiber, and the fiber collection method also explained in this study. Mask fiber is added to the concrete as an additive whose percentage is calculated based on the total weight of the concrete. The testing of this research is to be reviewed from compressive strength and material ductility.

SIGNIFICANT RESEARCH

One of the impacts of the pandemic is the increase in the generation of single-use mask waste, and if it is not handled correctly, it can contaminate the environment because the natural decomposition process takes a very long time. This study aims to determine the effect of adding mask fibers to the concrete mixture of compressive strength and ductility. In addition, the results of this study can also be used as a technical reference for making concrete with a mixture of mask fibers and recommend the optimum level of addition of mask fibers.

METHOD

The collection of mask fiber from domestic activities is an option considering that mask waste from health agency activities is not permitted because it has special procedures for handling it. Even though it is a domestic activity, the health protocol is still strictly applied, including sterilizing it before taking the fiber and mixing it into the concrete. Procedures for collecting, sterilizing, and extracting fiber follow strict protocols to prevent transmission of the virus. The collected masks were sterilized in a particular container with a disinfectant liquid, then dried under the sun, separated the ear rope and wire strip, and then the fibers were taken using a shredder or grater machine, as seen in Figure 1.

Sterilization — *Separation of wire and rope* — *Fiber extraction* — *Mask fiber*

FIGURE 1. The process of taking the mask fiber

Concrete constituent materials came from the Karangasem district, where property testing was initially carried out to make a mixed design. The concrete quality of 21 MPa was used in compressive strength to compose the mix design. The standard making, curing, and test of the concrete is following the SNI 2847-2019 (13), which refers to ASTM (American Standard Testing of Materials), including testing of aggregate properties (C33M) (14), making mix designs, mixing, and making test specimens (C31M) (15), and testing method of compressive strength (C39M) (16). Test the properties of the concrete constituent materials, such as density, specific gravity, moisture content and absorption of aggregates, sludge content of aggregates, and gradation of aggregates. After the properties test of the concrete constituents, it is continued with the preparation of a mix design with a target compressive strength of 21 MPa. The results of the mix design get the specific gravity of the concrete and the composition of the material, then a test specimen is made with the addition of mask fibers. The addition of mask fibers into the concrete is an added material determined from the weight of the concrete (specimen). Eighteen concrete specimens were made in cylinders with a size of 150mm x 300 mm. The mixture variations made in this study were 0%, 0.125%, 0.25%, 0.375%, 0.5%, and 0.75%. The number of specimens from each variation can be seen in Table 1, respectively.

TABLE 1. Quantity of specimens

Code	Variation in	Number of specimens
S1	0 %	3
S2	0.125%	3
S3	0.25%	3
S4	0.375 %	3
S5	0.50%	3
S6	0.75%	3
	Total	***18***

The compressive strength test does at 28 days using a Universal Test Machine with a capacity of 2000 KN. The test of the compressive strength machine and test scheme can be seen in Figure 2 and Figure 3. The compressive strength is tested in a vertical position and determined based on Equation 2 and Equation 3 for finding the average value of each variation.

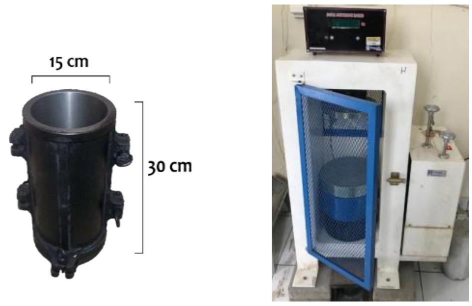
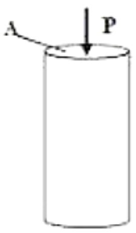


FIGURE 2. Specimen mold (left) and universal test equipment (right)



$$f'_c = \frac{P}{A} \quad (1)$$

$$f'_{c\,average} = \frac{\sum f'_c}{n} \quad (2)$$

P : Force
A : Area of circle
f'_c : compressive stresngth
n : number of specimens in same variations

FIGURE 3. Test scheme of compressive strength of concrete

RESULTS AND DISCUSSION

Testing Concrete Constituent Material Properties

Properties of concrete constituent material are used to determine the proportion of the mixture or mix design. The tested concrete constituent materials include cement, fine aggregate (sand), and coarse aggregate (gravel). The test follows the provisions of SNI 2847-2019 chapter 26.4.3, which also refers to ASTM C33M for specifications for coarse aggregate and fine aggregate. Properties testing of the concrete constituent materials, including bulk density, specific gravity, moisture content, aggregate absorption, sludge content, and gradation. The test results for each cement, sand, and gravel are shown in Table 2, Table 3, and Table 4. For each of these constituent materials will be used to make the mixed design.

TABLE 2. Properties of cement

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No	Parameter	Value	Unit
1	Fill weight	1.294	g/cm^3

TABLE 3. Properties of fine aggregate

No	Parameter	Value	Unit
1	Fill weight	1.554	g/cm^3
2	Specific	gravity 2.61	g/cm^3
3	Moisture content	20.89	%
4	Water absorption	6,61	%
5	Sludge content	7,2	%
6	Gradation	zone 2	

TABLE 4. Properties of coarse aggregate

No	Parameter	Value	Unit
1	Fill weight	1.341	g/cm^3
2	Density	2.43	g/cm^3
3	Moisture content	5.39	%
4	Water absorption	1.525	%
5	Sludge content	1.16	%
6	Maximum aggregate size	40	mm.

As shown in the table above, the results of property testing indicate that several conditions need to be adjusted, such as sand sludge content. The condition for the maximum content of sand silt is 5%, so it is necessary to wash it to reduce the sludge content so that it is at a value below 5%.

Mix Designs and Additional Proportions of Mask Fibers

Procedure and stages of making concrete mix proportions or mix designs follow SNI 2847-2019 article 26.4.3, referring to ASTM C31M and ASTM C39M. The proportion of each composing material is determined based on the strength of the design quality, environmental characteristics, and property testing results. The stages and results of the mix design can be seen in Table 5. The proportions of each material, namely cement, sand, gravel, and water, mix in surface saturated dry (SSD) conditions, so all aggregates to be mixed must be in SSD conditions. The density of concrete is 2200 kg/m3 as a reference to determine the percentage of addition of mask fiber. For each variation, three specimens were made for testing the compressive strength. The proportion of each concrete material for each additional variation of market fiber can be seen in the table.

TABLE 5. Mix design analysis and calculation

No	Description	Explanation	
1	Compressive Strength of Concrete 28 days, f_c	21	Mpa
2	Standard Deviation, SD	6	Mpa
3	Added Value, M	9.84	Mpa
4	Target Average Compressive Strength, f_{cr}	30.84	Mpa
5	Types of Cement	Type 1	
6	Types fine aggregate	natural	
7	Types of coarse aggregate	crushed	
8	water-cement ratio (w/c) count	0.56	
9	water-cement ratio (w/c) max	0.6	
10	slump	60-180	
11	Maximum aggregate size	40	mm
12	Maximum free moisture content	185	kg/m^3
13	cement content	330.36	kg/cm^3
14	minimum cement content	325	kg/cm^3
15	cement content used	330.36	kg/cm^3
16	adjusted w/c	0.56	

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17	gradation of fine aggregate	zone 2	
18	percentage of fine aggregate	0.3825	%
19	percentage of coarse aggregate	0.6175	%
20	The specific gravity of fine aggregate	2,370	g/cm^3
21	The specific gravity of coarse aggregate	2,378	g/cm^3
22	The specific gravity of combined aggregate	2,375	g/cm^3
23	The specific gravity of concrete	2200	kg/m^3
24	Combined aggregate content of	1684.64	kg/m^3
25	Content of fine aggregate	644.38	kg/m^3
26	Content of coarse aggregate levels of	1040.27	kg/m^3

TABLE 6. Material proportion

Mixed by weight (SSD)	water	cement	sand	gravel
Weight per 1 m3 of concrete material	185	330.36	644.38	1040.27
per concrete mixing ratio	0.56	1	1.95	3.15

TABLE 7. The mask fiber for each specimen

Specimen Code	Variations of masks fiber	Number of specimens	Mixture weight (g)	mask fiber required weight (g)
S0 (1-6)	0%	3	34.97	0
S1 (1-6)	0.125%	3	34.97	43.71
S2 (1- 6)	0.25%	3	34.97	87.42
S3 (1-6)	0.375%	3	34.97	131.14
S4 (1-6)	0.50%	3	34.97	174.84
S5 (1-6)	0.75%	3	34.97	262.26

Compressive Strength of Concrete

Testing of concrete strength refers to SNI 2847-2019 chapter 26.12.3 or ASTM C39M for testing concrete cylinders. The observations do from mixing to testing of compressive. The first test is a slump test done shortly after mixing and shows that all the mixtures added with mask fibers have decreased slump values and are close to zero. The addition of mask fibers indicates that the mixture becomes dry due to water being absorbed. The more addition of mask fiber, the higher the absorption occurred. Water absorption affects the workability of the concrete, and if the mixture is too dry, the making process will be more difficult. The slump test results can be seen in Figure 4. After the slump test, the test specimens were made with several variations, as shown in Table 1. A universal test machine tested all specimens for compressive strength at 28 days. Before being tested, all specimens were weighed first and showed the concrete with mask fiber lighter than the normal concrete. The test results for compressive strength can be seen in Table 8.

FIGURE 4. Mask fiber concrete mixture

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Normal ***With mask fiber***

FIGURE 5. Comparison of slump test

TABLE 8. Compressive strength

Specimen Code	Level of Fiber (%)	Compressive Strength (MPa)				Decrease (%)
		1	2	3	average	
S1	0	22.10	25.96	20.21	22.76	0.00
S2	0.125	24.24	19.42	18.23	20.63	9.34
S3	0.250	19.74	17.09	19.40	18.74	17.63
S4	0.375	19.94	12.31	18.30	16.85	25.95
S5	0.500	13.29	13.68	14.35	13.77	39.47
S6	0.750	9.44	10.59	9.17	9.73	57.23

The test results show that the addition of mask fibers causes a decrease in the compressive strength of all test objects. The compressive strength at variations of 0.125% and 0.25% is 20.63 MPa and 18.74 MPa, which still meets the requirements for structural concrete in general according to SNI 2847-2019 chapter 19.2.1.1. As for the compressive strength for variations of 0.375% to 0.75% below 17 MPa, which does not meet the requirements of structural concrete. The trend of the compressive strength based on the test results can be seen in Figure 5. The decrease in compressive strength shows that the addition of mask fiber as an added material affects the strength of concrete, which is water-cement due to being absorbed by the mask fiber. At the time of mixing the mask fiber, cement and water were not added to control the cement's water content (w/c) consequence of adding mask fiber. This is the main cause of the decrease in the compressive strength of concrete due to the decrease in cement content due to the addition of mask fibers.

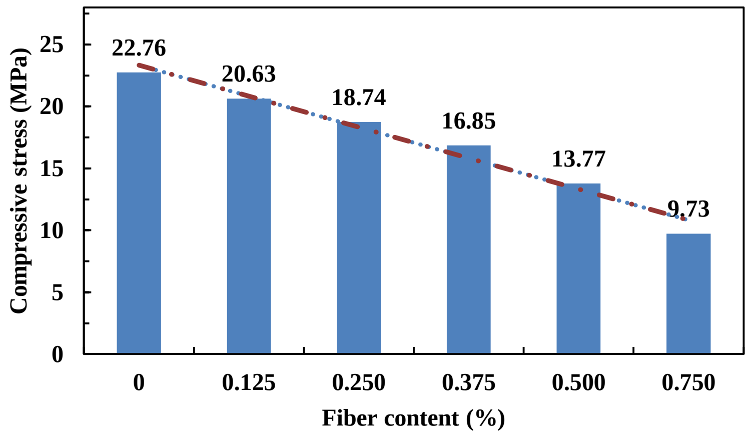

FIGURE 6. Graph of compressive strength

However, there is a significant difference in the destruction of concrete with and without fiber masks. Concrete without fiber undergoes destruction as soon as the peak load is passed, which is initiated by cracking and widens rapidly to some parts separately off. Meanwhile, the concrete with mask fibers cracked after it reached the peak load, but when the deformation continued to be increased, the cracks widened slowly but remained. This shows if the concrete with mask fibers has higher ductility than normal concrete or the ductility improved due to the addition of mask fibers. The existence of fibers keeps the concrete tightly together, as can be seen in Figure 6.

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(without fiber) *(with fiber)*

FIGURE 7. Crack after compression test

Based on the test results obtained and considering the advantages and disadvantages of concrete due to the addition of mask fibers, it is recommended the optimum value of adding mask fibers to concrete is 0.125% by weight. The addition of 0.125% content considers the decrease in compressive strength by 10%. With 0.125% of the mask fiber added to the concrete mixture, it estimates can absorb 2.75 kg of mask waste per m3 of concrete or the equivalent of 687 masks.

Comparison Concrete Fiber in Other Research

Fiber concrete has been widely studied and has advantages in increasing its ductility compared to normal concrete. The fiber used in the concrete mix comprises several materials that can be categorized into four fiber materials. The categories of fiber in fiber concrete are steel fiber, glass fiber, plastic fiber, and natural fiber. Steel fiber is usually made from pieces of wire and also be waste material from steel in the form of fiber. Glass fiber is an artificial fiber made with a special purpose for concrete materials such as carbon fiber (CF). Then plastic fibers consist of several basic materials: polymer, polyethylene, polypropylene, or nylon. The natural fiber is made from natural materials such as coconut fiber, palm fiber, pineapple leaves (bagu), and others. Several previous researchers on fiber concrete have been carried out can be seen in Table 9. The results shown from several studies in Table 9 show that the addition of fiber increases the ductility value more than normal concrete. In other words, it reduced the concrete brittle. The addition of mask fibers to concrete did reduce the compressive strength of concrete as in other studies, although some experienced an increase after the addition of fibers.

TABLE 9. Research of concrete fiber

Author	Fiber	The optimum level of addition (%)	Compressive strength (MPa)	Additional information
Wang (1996)	Carpet Waste (polypropylene, latex rubber, nylon)	0.47% of concrete weight	27.6	The fibers hold the concrete matrix tightly together so that the concrete is still integrated.
Salain (2014)	Coconut fiber	1.5% of concrete volume	35.31	Fiber plays a role as discontinuous micro-reinforcement, which reduces the brittleness of the concrete, thereby increasing the capacity of the concrete.
Apriliawati 2016)	Waste cutting banner (polyvinyl and nylon)	0.2% of concrete weight	21.79	Increasing the fiber more than the optimal level can reduce workability and capacity due to the high water absorption of the fiber.
Yanti (2019)	Pineapple leaves	5% of cement weight	22.16	There was no significant interaction in the compressive behavior with the addition of fiber, but the flexural behavior did occur.

Current study	Mask waste (polypropylene)	0.125% of concrete weight	20.63	Fiber addition can reduce the compressive capacity, but it increases the ductility, so the crack is slowly opened after reaching peak load.

CONCLUSION

Recycling is done using the solidification method, which adds it as an additive to concrete as a construction material. The results of this study recommend that the optimum addition of mask fiber as an additive is 0.125%. The strength of concrete with a mask fiber content of 0.125% still meets the requirements for the strength of structural concrete in general and provides other advantages, namely increased ductility. The estimated absorption of mask waste with 0.125% is 2.75 kg per m3 of concrete or 687 masks. This method of recycling single-use mask waste into an added ingredient in the concrete mix is an alternative to reduce waste generation. Further research needs to be done to increase the volume of masks that can be added to concrete with a constant cement content, expand the study of parameters, and it is necessary to study economically for commercial needs.

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