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Concrete Repair Using Fiber from Surgical Mask

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Abstract: In this new Norma, surgical mask was a thing that important to wear in public. Because of the frequent use of surgical mask, the huge of waste of surgical mask were disposed per day. The surgical mask was made from a polypropylene fiber that widely used in construction in the term of concrete fiber. Polypropylene fiber had their own credibility to provide the ductile strength for concrete to reduce the cracking of concrete that was a brittle material. To study the effectiveness of the fiber from surgical mask, this fiber was used as concrete repaired materials The material of concrete repair was the important things to provide or improved the deteriorated concrete. Therefore, this study will determine that fiber from surgical mask can be used as a concrete repaired material through the comparison of flexural strength between the controlled concrete and repaired concrete. Three methods of concrete repaired was tested in this study, single layer polypropylene fiber, single layer surgical mask fiber, and double layer surgical mask fiber. Those method was applied to deteriorated concrete prism. The result for flexural strength of concrete after repaired for all method was decreasing from the strength before repaired but the result of second method was higher than the first method and the third method was higher than the second method. The concrete failure condition, showed the failure happened on the same location failure before repaired that meant the failure happened on the concrete repaired material. However, the used of surgical mask fiber was changed failure condition of the concrete prism from sudden failure to periodic failures. Therefore, the surgical mask was effective to repair the damage concrete due to crack failure because the fiber of the surgical mask can have controlled that crack.

Keywords: New norma, surgical mask, polypropylene fiber, concrete repair, deteriorated concrete, sudden failure, periodic failure

1. Introduction

Concrete is a structure component that contains cement, fine aggregate, and coarse aggregate with a various mixing ratio. The concrete structure was highly recommended than other structure such as steel or timber because of the properties of concrete [1]– [3]. One of the superiority of concrete is based on the physical properties that high in compressive strength, but the deficiency of concrete is less in tensile strength [1]– [5]. Because of this deficiency, the materials in the concrete have been added with other materials such as fiber, rubber, and foam.

From this study, one of the other materials "fiber" have been used to be added in the mixing concrete. The effect of compressive strength, elastic modulus, flexural strength, and deflection in concrete fiber was increasing than the normal concrete [5]." Therefore, in this project, the fiber will be used for the concrete repair based on the flexural strength. For the selecting fiber, the fiber from surgical mask will be used as a type of fiber. This because of this new normal, there were a lot of waste that came from surgical mask. The waste from surgical mask was binned up to 10 million per day [6].

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Therefore, this study was used the disposal surgical mask as a fiber for concrete repair to study the effectiveness of surgical as repaired material and to determine the best method to repair concrete damage using the surgical mask.

2. Concrete Repaired

Concrete repair was the maintenance work on the concrete or structure that has a damage on it. This repair means that work of changes and fix a problem [7]. That means the problem occurs on the concrete and it will be fixed and solved it was called as concrete repair. The problem occurs on the concrete can be cracking, corrosion, damage impact or fire during the lifetime of concrete [8]. Because of this problem, it made the concrete deteriorated, the strength concrete will decrease until failure. Therefore, to prevent the concrete failure, the concrete repair work must be done.

In concrete repair, the material selection was important to produce a strong structural to able carried the load in the future and also to prevent any damage happen again. In United State the performance of repairing the concrete was just 50% successful and the unsuccessful repair was because of wrong selecting materials [8].

Table 1 - Previous study of concrete repair

No	Description	Result	Ref.
1	Study on a concrete beam that been deteriorated by break the concrete in two pieces. Samples of beam have produce for this study and the beam will have 2mm width and 10 mm depth as a notch at the middle for early crack and to break the concrete into two pieces. This broke samples will be repaired with 0%, 10%, 20% and 40% of sand in the epoxy mortar in the crack width of 1mm, 5mm and 10mm. The repaired procedure was fill the epoxy mortar with sand percent in the crack width. The testing that been done was the three point loading testing to determine the fracture of the beam.	The result of this study shown the improvement of concrete weakness by using the type of concrete repair. In the 1mm crack width, the fracture strength was increasing to 122% and 228% compare to the original concrete. Also for the 5mm and 10mm crack width the fracture strength was increase by increase percent of sand in the epoxy mortar.	[9]
2	Study on a deteriorated reinforced concrete beam that been preloaded with the 60% of load capacity of beam until 0.2mm crack width appear. That broken beam will be repaired by covered the tension face with the three type of FRP sheet which is GFRP, CFRP, and CFRP laminate. One of that beam will be test until failed as a control beam. Then all repaired beam will be testing on the three-point bending test to determine the deflection of every repaired beam and the result will be compared.	The result of this study was all three type of FRP sheet that been used to repair the deteriorated concrete has a result that was higher compared to the controlled beam. Therefore, they conclude that this FRP sheet was good to use as a concrete repair material. Also in this result, shown the type of failure that happened on the repaired concrete.	[10]
3	Study on a deteriorated concrete cylinder that been damaged by heat with various temperature 20º, 200º, 400º, 600º, and 800º Celsius. The 20ºC will be used as a controlled sample and will not be repaired. The other samples will repair with the BFRP jacket wrapped the damage sample with 2, 3 and 4 layers of BFRP jackets. Then, all samples will be tested under the compressive test to determine the compressive strength and strain.	The result of this study shown that the damage concrete can increase their strength in compressive and strain by using this repaired method. The test result shown the increasing of the samples strength. Therefore, this means that the BFRP jacket can be used as concrete repair material.	[11]
4	Study on a deteriorated reinforced concrete column that been damage by corrosion from direct current. The sample column will be submerged in the water that will supply the electric current to the column. After the sample column was corrosion, the repaired method will be conducted toward that column. The repaired method that will be used was installed NSM strip, wrapped CFRP sheet or both. All repaired column will be test under the compressive load using universal testing machine with 2000kN load.	The result of this study shown the comparison in strength between three type concrete repair methods. The first method by installed NSM strip, the result does not show the improvement in strength between the original columns. The second method by wrapped CFRP, result shown the improvement in 15% and 21%. The method by using both method had the highest improvement.	[12]
5	Study on a deteriorated reinforced one way and a cantilever slab that was been preloaded up to 0.7Pu	The result of this study shown the improvement of strength in reinforce	[13]

load of cracking. One slab will be used as the controlled samples without and repair method. Two slabs will be repaired by wrapped with the glass fiber. The other two slabs will be repaired by installed the anchors and wrapped with the glass fiber. All slab will be tested on the two-point loading, one loading at the mid span of one-way slab and the other one at the end of cantilever. The loading will have produced by hydraulic jack.	concrete slab after repaired from the original slab. The repaired method by using glass fiber was the possible method in concrete repair. But, to improve more strength in the structure, adding with the anchors was the best method that was shown the result in this study.

3. Materials and Methods

3.1 Materials

3.1.1 Fiber

In general, fiber was defined as a material that produced by natural or human-made that formed like a thread or filament. The application of fiber was mostly being applied in the construction field. Fiber in concrete was defined as a composite material that was a good potential in improve the strength of concrete [14]. This fiber mostly used in concrete to provide more compressive, tensile and flexural strength. It also was used to control the cracking that happen because of shrinkage in concrete.

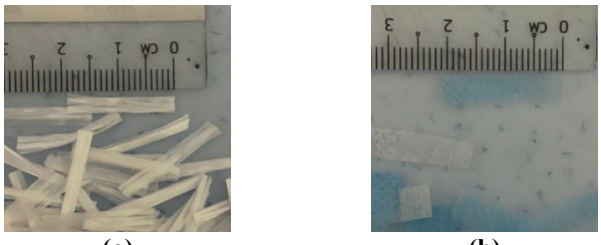
3.1.2 Surgical Mask

Surgical mask was one of the main personal protection equipment (PPE) during this corona virus diseases outbreak. This surgical mask was functional to be used as a filtration of the virus to flow in from the atmosphere to mouth and nose and to flow out from mouth and nose to atmosphere. The 3-ply mask was means that mask has three different layer with different function. This 3 layer of mask was produces by non-woven fabric or polypropylene fiber [15]. The surgical mask was a material that made by polypropylene fiber non-woven fabric, the standard size was 17.5cm x 9.5cm, weight range 20 to 25 gsm in density, thickness was 0.3 micron per layer and modulus of elasticity was 0.008 to 8.25 GPa [16].

3.2 Method

3.2.1 Material Preparation

The waste of surgical mask was collected in the period time in 6 month or until got a large quantity of mask. The surgical mask was collected in the closest society such as family members or housemate. Then the surgical mask was treated on this virus or bacteria that filtrated in the layer of the surgical mask. The treatment of the surgical mask was used chemical treatment by submerged it into water contains 5% of sodium hypochlorite (bleach) [17]. The last procedure was the surgical mask was cut into pieces with this dimension 2mm width and 20mm length. This dimension was referred to the standard manufactured polypropylene fiber dimension. Fig 1 shows the fiber material that used, polypropylene fiber was used as a controlled result.



(a) **(b)**

Fig. 1 - Fiber materials (a) polypropylene fiber; (b) surgical mask fiber

The concrete sample will be made with the mixture ratio of 1:1:2 as a sample of concrete with water cement ratio 0.5. There two type of samples that casted for this study concrete cube and a concrete prism. The concrete prism was followed this dimension 100mm x 100mm x 400mm. Nine samples of the concrete prism will be casted. For the concrete cube, the dimension was 150mm x 150mm x 150mm and six samples will be casted.

3.2.2 Sample Testing

Two method of testing will be used in this study. The first method was a cube test to determine the compressive strength of concrete and the second method was a three-point bending test to determine the flexural strength of concrete. The testing procedure was referred to BS-EN 12390-3 cube test [18] and BS-EN 12390-5 three-point bending test [19].

The cube test was conducted to determine the compressive strength of concrete mixture ratio 1:1:2 that need to achieve grade C25/30. Therefore, the result of compressive strength was used to determine the strength properties of concrete. Three of that samples were tested after 28 days of curing to achieve 100% of concrete strength. Other three samples, was tested at the same day with repaired concrete prism test (44 days). This cube test was to investigate the changes of concrete strength that was related to flexural strength after concrete repaired.

The three-point bending test was conducted to determine the flexural strength of concrete. In this test, the nine samples of the concrete prism were tested to determine the maximum flexural strength of concrete for each prism. The result of maximum flexural strength concrete was used as a controlled result for the flexural strength of repaired concrete. After the concrete prism failed because of the testing, all concrete prism was repaired according to the method that proposed in this study. Then, the repaired concrete prism was tested again on the three-point bending test to determine the maximum flexural strength concrete after repaired. The result of the flexural strength concrete after repaired was compared to the controlled result. From the three-point bending test also, the force versus deflection graph was obtained. Fig. 2 shows the schematic drawing of the three-point bending test procedure.

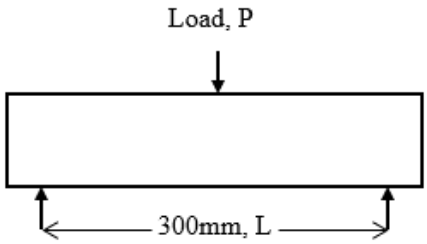


Fig. 2 - Schematic drawing of three-point bending test

3.2.3 Concrete Repaired

This study was proposed three method of concrete repaired. The first method was wrapped the crack line with the single layer epoxy adhesive layer and polypropylene fiber in horizontal arrangement. This method was used to be a controlled result because the usage of polypropylene fiber was usually used in concrete repaired material and also because the material characteristic of surgical mask was made by polypropylene fiber. The second repaired method was used the single layer adhesive epoxy with surgical mask fiber in horizontal arrangement and the third method was use double layer adhesive epoxy with surgical mask fiber in vertical and horizontal arrangement. Each method of repaired concrete has three samples of the concrete prism that used to be repaired. The result from these three repaired method will have compared each other to determine the best method of repaired concrete. The adhesive epoxy was used because epoxy material was the best concrete repaired material according to (Kiani et al. 2018). Adhesive epoxy also was used to stick the fiber on the crack line. Fig. 3 and 4 shows the schematic drawing of the concrete repaired method for each method.

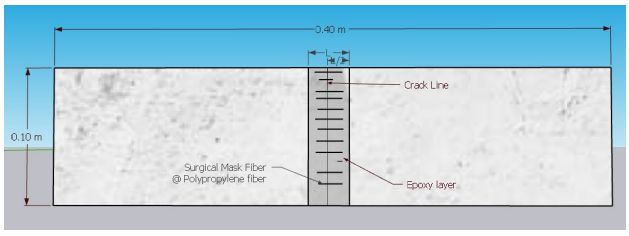


Fig. 3 - Schematic drawing 1st and 2nd method

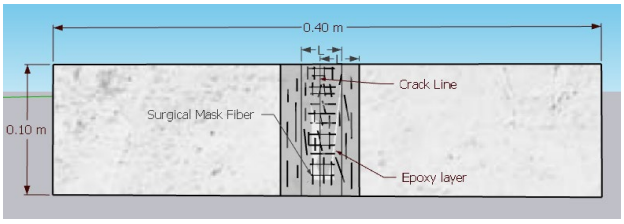


Fig. 4 - Schematic drawing 3rd method

3.3 Equations

$$f_{cf} = \frac{3 \times F \times L}{2\, d_1\, {d_2}^2} \tag{1}$$

Where:

f_{cf} : Flexural strength of concrete specimen in MPa
F : Maximum load of test in N
d_1, d_2 : Lateral dimension of specimen in mm
L : support spacing in mm

$$w_o = \frac{FL^3}{48EI} \tag{2}$$

Where:

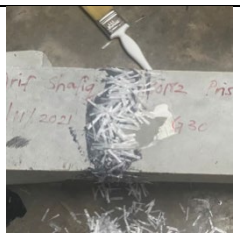
w_o : Deflection in mm
F : applied loading in N
L : support spacing in mm
E : Modulus of elasticity (14GPa – 41GPa for concrete)
I : Moment inertia in mm4

4. Results and Discussion

4.1 Repair Method

Table 2 shows the condition of the concrete prism before repaired and after repaired based on each proposed three methods.

Table 2 - Image of before and after concrete prism repaired

Repair Method	Prism	Before	After
Single layer epoxy adhesive with polypropylene fiber (horizontal arrangement)	1		
	2		
	3		

Single layer epoxy adhesive with surgical mask fiber (horizontal arrangement)	4		
	5		
	6		
Double layer epoxy adhesive with surgical mask fiber (horizontal and vertical arrangement)	7		
	8		
	9		

4.2 Compressive Strength

Table 3 Results of compressive strength of concrete

Days	Compressive strength (MPa)		
28	35.1	42.4	42.1
Average		**39.8**	
44	49.1	47.3	44.7
Average		**47.0**	

Based on Table 3, the average compressive strength of concrete after 28 days was 39.8 MPa higher than 30 MPa that achieved the target grade of concrete C25/30. Also from the result, there were changes in increment of compressive strength after 44 days up to 18% of compressive strength. Therefore, there was no effected to the result of flexural strength after repaired.

4.3 Flexural Strength

Table 3 - Results of flexural strength of concrete

Prism		Weight (kN)	Repaired Condition	Maximum Force (kN)	Flexural Strength (MPa)
First Method	1	0.091	Before	8.866	3.990
			After	1.716	0.772
		Percent Strength (%)		**19.4**	
	2	0.093	Before	10.725	4.826
			After	2.860	1.287
		Percent Strength (%)		**26.7**	
	3	0.090	Before	8.151	3.668
			After	1.573	0.708
		Percent Strength (%)		**19.3**	
Second Method	4	0.089	Before	7.722	3.475
			After	2.431	1.094
		Percent Strength (%)		**31.5**	
	5	0.090	Before	7.293	3.282
			After	2.574	1.158
		Percent Strength (%)		**35.3**	
	6	0.090	Before	8.294	3.732
			After	3.003	1.351
		Percent Strength (%)		**36.2**	
Third Method	7	0.092	Before	9.581	4.311
			After	8.723	3.925
		Percent Strength (%)		**91.0**	
	8	0.091	Before	7.436	3.346
			After	5.148	2.317
		Percent Strength (%)		**69.2**	
	9	0.091	Before	8.294	3.732
			After	6.578	2.960
		Percent Strength (%)		**79.3**	

Table 4 shows the analysis of flexural strength of concrete before and after repaired using the three proposed method. From this analysis, all the three method was not effective to be the repaired materials or methods because the result of flexural strength after repaired lesser than before repaired. But, this result shown that using surgical mask was more effective than using original polypropylene fiber. This statement was supported by the different of percent strength between the three methods. The percent range for the first method using polypropylene fiber from 15% to 30%, then for the second method using single layer or surgical mask, the percent range from 30% to 40%, and the last method using double layer of surgical mask was 75% to 95%. Therefore, this result conclude the flexural strength of repaired concrete was increasing by using surgical mask than the polypropylene fiber.

4.4 Force Deflection Graph

Table 5 - Deflection at Force 1.5 kN

Prism		Force (kN)	Before Repaired		After Repaired
			Deflection Theory (mm)	Deflection Experiment (mm)	Deflection (mm)
First Method	1	1.5	0.007	-0.040	0.192
	2	1.5	0.007	-0.500	0.600
	3	1.5	0.007	-0.320	0.570
Second Method	4	1.5	0.007	-0.900	0.210
	5	1.5	0.007	-0.025	0.290
	6	1.5	0.007	-0.048	2.080

Third	7	1.5	0.007	-0.450	0.670
Method	8	1.5	0.007	-0.475	0.950
	9	1.5	0.007	-0.165	0.380

Table 5 shows the result of deflection at 1.5kN force for concrete before and after repaired. The before repaired data, the result from theory calculation and experiment data, the data from experiment was not the deflection data because the deflection that should be must nearest to 0.007mm. This result showed that the compression appears during the test and produce negative data. The after repaired data, the difference of deflection data at 1.5kN force. The comparison of deflection between before and after concrete repair have a large difference for all three methods of repaired. Therefore, the method of concrete repaired was not unable to improve strength capacity of the concrete prism.

4.5 Concrete Prism Failure

Before repaired, the concrete prism was a sudden failure after achieve maximum force and the concrete prims were split into two parts. This is because the concrete was lack in bending stress and it cannot have made an initial crack during testing. Figure 5 showed the condition of concrete failure before repaired.

Fig. 5 - Concrete failure before repaired

While after repaired, the failure of the concrete prism was showed the crack pattern of concrete. From the crack pattern, it showed that cracking happened slowly because of the fiber still tied the cracking. Each three methods, shown the same result for the crack pattern, therefore using fiber or surgical mask can support the concrete in increasing the bending stress to make the concrete was not sudden failure. By using polypropylene fiber and surgical mask also will give an early warning before concrete fail in real live condition.

Fig. 6 - Failure after repaired (1st Method)

Fig. 6 shows the polypropylene fiber controlled the crack happened during the testing. The polypropylene fiber still tied the concrete failure from splitting.

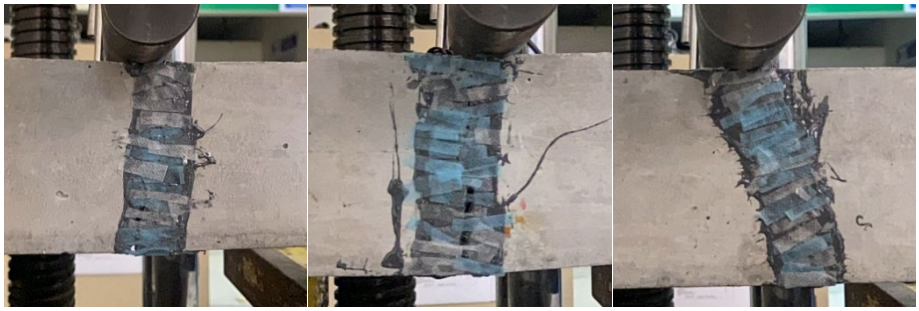


Fig. 7 - Failure after repaired (2nd Method)

Figure 7 also shows the condition of cracking and failure for the second method by using surgical mask. It showed the crack width was smaller than the first method. Therefore, it concludes that the concrete repair method using surgical mask was more efficient and suited than the polypropylene fiber.

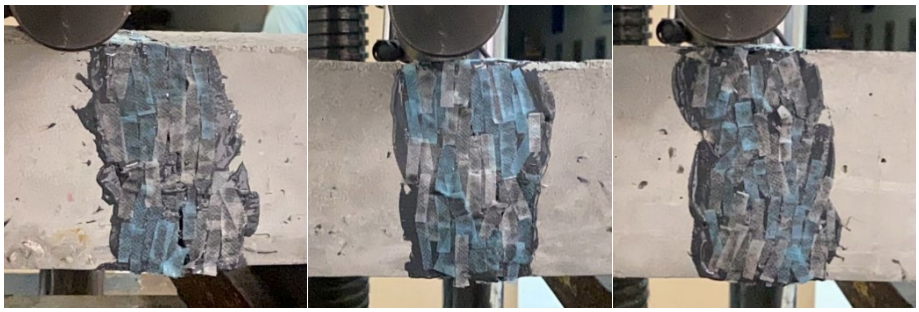


Fig. 8 - Failure after repaired (3rd Method)

For the third method by using the double layer of surgical mask, the condition of cracking and failure were shown in Figure 8. This method was stronger and efficient than the other two methods because the crack width was smaller than the other two methods.

Based on the all three method of concrete repaired, failure happened on the same location and condition with the concrete prism before repaired. That was meant that repaired concrete failed due to the previous crack line that been repaired. This result conclude that the failure occurs on the repaired materials and the repaired materials were not enough to bond the deteriorated concrete prism. Also, based on the failure condition of the repaired concrete prism, it showed that failure happened on the adhesive epoxy layer first and the fiber still joined and tied the bonding of the concrete prism. This result concludes that adding fiber on the adhesive epoxy was functional in increasing the strength of the bonding on concrete repaired.

5. Conclusion

From the result of this study, the repaired method that used surgical mask provide more strength than the polypropylene fiber. Therefore, it concludes that surgical mask was more efficient than polypropylene fiber as a repaired material. But the result of the strength of the repaired concrete using surgical mask was not achieving 100% strength of concrete. Therefore, this studied conclude that using surgical mask as repaired material was not effective in repaired total failure of concrete. But it also can conclude that using surgical mask was effective in repaired early failure of concrete such as cracking. This was because the result for concrete failure analysis showed the functional of surgical in controlling the crack during failed. Lastly based on the problem of this study of the huge wastes of the surgical mask that happened because of the Covid-19 will be reduced by using the disposal surgical mask in the construction field. Although, this study was not achieved the target in increasing the flexural strength result of repaired concrete higher than the before repaired concrete. The other analysis was showed an improvement result by using the surgical mask as a concrete repaired material. Some recommendation that provided to improve the study of effectiveness surgical mask as concrete repaired material.

- Study this concrete repaired method by using the surgical mask on the reinforcement concrete because it related to the real life condition of structure such as beam, slab or column. Also, the condition of deteriorated concrete will be not in total damage condition.

- For the total failure concrete liked the concrete prism split into two, used method of concrete repaired by a used epoxy resin layer on the 1mm crack width [9] to fully bond inside the broken concrete prism. Then, used the surgical mask to wrap on the outside concrete surface to give more strength.
- Study the other concrete repaired method also by using the surgical mask, but used the surgical as a fiber strip not fiber piece. Because the method of using surgical mask as a fiber piece needs more worked in preparation of small pieces of surgical mask.
- Apply more width of wrapping layer of concrete repaired on the crack line and also used the length surgical mask pieces more than 20mm length. This approach maybe can give more strength on the deteriorated concrete because the surgical mask will be more tied the crack line and not easy to split.
- The pieces of surgical mask also can be used in the concrete mixture as a fiber reinforcement concrete because the result of the surgical mask was more efficient than polypropylene fiber that mostly used in fiber reinforcement concrete.

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