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EFFECTS OF COLD JOINT AND ITS DIRECTION ON THE COMPRESSIVE AND FLEXURAL STRENGTH OF CONCRETE

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ABSTRACT: A cold joint is the main problem in concrete construction, especially in large quantities such as mass concrete. The capacity of mixing plan and manpower make monolith casting is impossible. The distance between the batching plant and the construction location is also an obstacle to cold joints. This study would test the compressive and flexural strength due to the effect of cold joint in concrete. The period of the casting between two concrete (cold joint) was 120 minutes and 240 minutes. Tests carried out in the form of compressive strength and flexural strength of the vertical and horizontal directions of cold joints. The types of concrete used in this study include normal concrete with 35 MPa compressive strength, concrete with high initial compressive strength using superplasticizer, and concrete using polypropylene fiber as added material. Compressive and flexural strength tests were carried out at 3, 7, 14 and 28 days. All specimens used water curing up to the predetermined test life. The test results show that specimen with the cold joint connection in normal concrete has a decrease in quality (flexural and compressive), so does with the concrete with superplasticizer (high early compressive strength), whereas in concrete using fiber has increased in strength compared to normal concrete without cold joint connection.

Keywords: Compressive Strength, Flexural Strength, Cold Joint, Fiber Concrete, High Strength Concrete

1. INTRODUCTION

Concrete is one of the construction materials, which is the most widely used because it has many advantages such as cost-benefit, stable material supply, and has a high level of durability [1]. However, concrete also has a weak tensile strength, so cracking occurs quickly due to tensile stress [2]. Generally, concrete also uses as a material for infrastructures such as a dam, pavement, bridge, which makes it very difficult to be monolithically cast at the same time. In general, concrete is cast in a gradual time so that several layers are formed where the boundary between these layers is better known as a cold joint. The amount of concrete that can be worked depends on the project conditions and the capacity of the mixing plan [3]. Cold joints that occur in concrete significantly affect the performance and durability, so that further analysis and research needs to be done on the strength of concrete due to the cold joint.

Research on cold joint and reinforcement carried out has been previously studied, including the effect of the presence of cold joint on the compressive strength of concrete [3], a fracture that occurs due to the presence of cold joint [4, 7], shear stress due to cold joint after the final setting time [5], and evaluation of bonding shear performance due to the presence of cold joints in concrete [6]. In addition, there are also several tests relating to material conditions and environmental conditions in the concrete due to the cold joint, including testing the effect of the cold joint on concrete using recycled aggregate [8], the influence of hot weather conditions on concrete containing cold joint [9], cold Joint in self-compacting concrete [10], and cold joint in rolled compacted concrete [11].

This study will variate the material used with the normal concrete, concrete with high initial compressive strength using superplasticizer added ingredients and concrete using polypropylene fibers. Concrete with high compressive strength is not a strange thing in construction science, but there are not many studies that discuss the effect of the cold joint on high compressive strength concrete. Research on high strength concrete in general has focused on its compressive strength. Several studies on high strength concrete have been carried out, including testing shear friction due to friction between concrete and concrete [12].

Besides, this research will also use polypropylene fiber as an added material to increase the tensile strength of concrete, especially in flexural testing. Fiber has been used very often in flexural and tensile tests on concrete. This study will use a compressive and flexural test on concrete joints containing cold joints. The use of polypropylene fiber in concrete includes mechanical properties of hybrid fiber reinforced concrete [13, 14], microscopic test, physical and mechanical analysis on fiber reinforced concrete [15], and durability testing of fiber concrete using polypropylene [16].

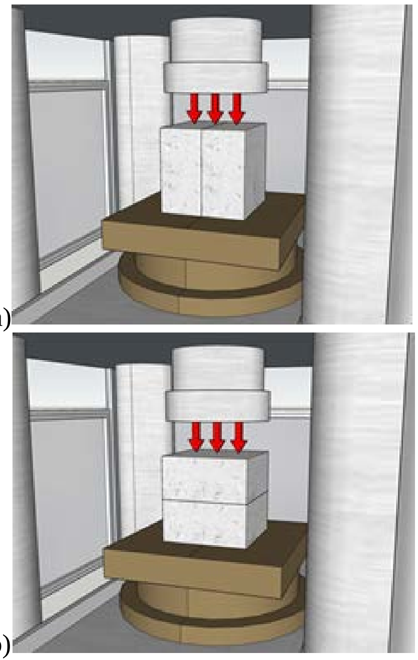
This study tested the compressive strength and flexural strength of concrete using three types of concrete: normal concrete, high compressive strength concrete and fiber concrete. Besides, the cold joint effects will be examined with the vertical and horizontal directions of loading. The time of casting delay in this study was 120 minutes and 240 minutes. The compressive strength and flexural testing were performed at various ages, namely 3, 7, 14 and 28 days. Testing for 3 days was only done on specimens with superplasticizer added ingredients.

2. EXPERIMENTAL PROGRAM

This study tested the compressive strength and flexural strength due to the cold joint in concrete. The material used consists of cement, water, fine aggregate, coarse aggregate, superplasticizer and polypropylene fiber. Variation of casting time was 120 minutes and 240 minutes with vertical and horizontal joint directions. The time variations used is the estimated time of late arrival of the mixer truck in the casting process in Indonesia. The direction of testing conducted can be seen in figure 1. In this study, there was a variation that does not use cold joint to determine the effect of the cold joint on concrete. Before conducting concrete testing, testing the coarse and fine aggregate properties was performed first, as shown in Table 1. The aggregate properties test consists of testing the moisture content, specific gravity, absorption, mass density, mud content and roughness content. In this test, it can be concluded that all of the aggregates used to meet the standards for use as concrete compilers.

In the process, the slump value was tested first to determine the workability of fresh concrete. After this, the compressive strength and flexural strength were tested. This test was carried out at ages 3, 7, 14 and 28 days. Adjust variations of the mix proportion was used. Compressive strength testing was used on cube specimens measuring 100 x 100 x 100 mm^3 (Fig. 1). The compressive strength testing standard used refers to ASTM C39 [17]. The curing method used in this study was water curing for 28 days. Flexural strength testing used 150 x 150 x 600 mm3 specimens with flexural testing method refers to ASTM C239 [18]. In compressive strength testing, each testing age consisted of 3 samples which are then averaged the results. Whereas the flexural testing only used 2 samples in each variation for each curing age.

This study used 3 types of variations. Table 2 are the mix proportion used for each variation. V-0 is normal concrete without a cold joint, and this concrete will use as a control to check the compressive and flexural strength because of the cold joint effect. The variation V-2 used a superplasticizer added with 0.5% of cement weight and experienced a reduction of water by 30%. Meanwhile, specimen V-3 used fiber-added ingredients of 0.5% by weight of cement and without the use of superplasticizer-added ingredients. The fiber length around 3-5 cm with a width between 1-2 mm. The mix design method used in this study refers to the ACI 211.1 standard [19]. The superplasticizer used is a type of Bestmittel which aims to reduce water use and increase the initial compressive strength so that in the V-2 variation, the compressive strength is tested at the age of 3 days, whereas in other variations, it begins with testing at the age of 7 days.



(a)

(b)

Fig. 1 Compressive strength test (a) Vertical direction; (b) Horizontal direction

Table 1 Mechanical Properties of Coarse and Fines Aggregates

Test Item	Unit	Fines Aggregate	Coarse Aggregate
Water Content	%	6.17	3.71
Specific Gravity	-	2.54	2.58
Absorption	%	4.83	2.82
Mass Density	g/cm^3	1.52	1.54
Mud Content	%	2.00	0.92
Roughness content	%	-	32.87

Table 2 Mix Proportion for 1m^3

Materials (Kg)	Normal Concrete (V-0 and V-1)	Concrete with Superplasticizer (V-2)	Fiber concrete (V-3)
Cement	439.2	439.2	439.2
Fines Aggregate	646.1	646.1	646.1
Coarse Aggregate	1039.5	1039.5	1039.5
Superplasticizer	-	2.1	-
Polypropylene Fiber	-	-	2.1
Water	181.8	181.8	181.8

3. RESULTS AND DISCUSSION

The test result of this study consisted of two parts, fresh properties results consisted of a slump test and hardened properties consisted of compressive strength and flexural strength testing.

3.1 Slump Test

Slump test was performed on each variation. Figure 2 displays the results of the slump value for each variation. V-1 and V-0 produced slump flow values of 9.5 cm, while variation V-2 produced a slump value of 8.7 cm. This reduction in slump value was due to the amount of water being reduced by 30%. At the same time, the variation of V-3 produced a slump value of 8.0 cm. slump value on V-3 decreased due to effect of the amount of fiber. However, all the slump results obtained meets the specified workability standards.

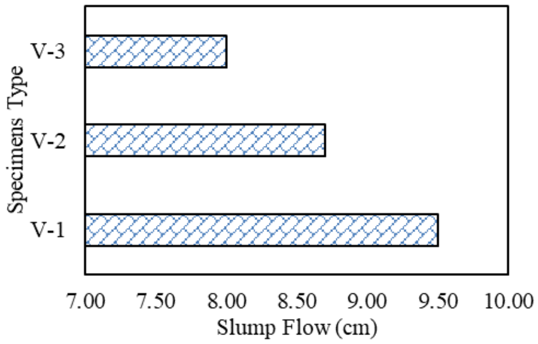
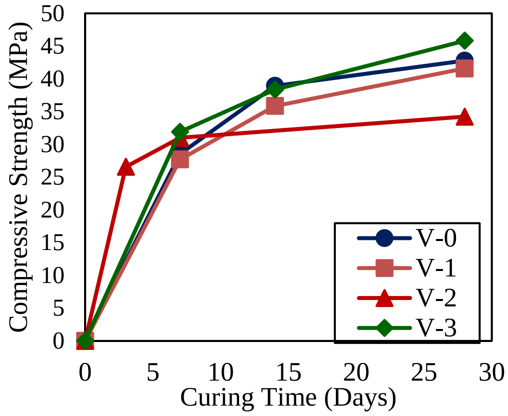


Fig. 2 Slump Test Result

3.2 Compressive Strength

Compressive strength testing was carried out with the cold joint's vertical and horizontal directions, as shown in Figure 1. The casting time range was 120 minutes and 240 minutes. Figure 3 is the result of compressive strength testing with a varied range of 120 minutes. Figure 3 (a) explains the compressive strength results by the vertical direction testing, while Figure 3 (b) explains the results of the compressive strength tests in the horizontal direction. The horizontal direction testing showed that at the age of 7 days, there was no significant difference between concrete with a cold joint and without a cold joint. However, in the 28 days age test, there were differences in the results of compressive strength. Concrete V-2 produced the smallest compressive strength on the 28 days age test in the vertical cold joint direction. In the vertical direction test, the highest compressive strength was obtained by the V-3 specimen in which in the horizontal direction test, it produced the lowest compressive strength. This is due to the effectiveness of the fiber used. In the vertical direction test, the fiber works at the joint due to the cold joint, whereas in the horizontal direction test, the fiber cannot work effectively.



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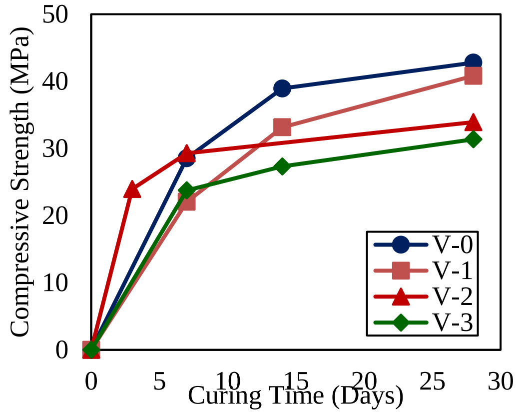
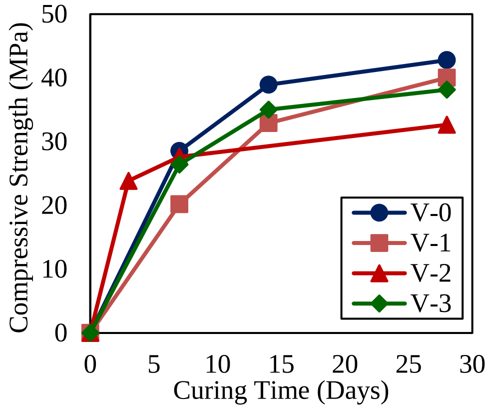


(b)

Fig. 3 Compressive strength with 120 minutes cold joint (a) Vertical direction (b) Horizontal direction

Figure 4 is the result of compressive strength testing with a 240-minute casting interval. Fig. 4 (a) results from compressive strength testing with cold joint vertical direction, while Figure 4 (b) is compressive strength testing with the horizontal direction. This test, both the vertical and horizontal directions, produce compressive strength under normal concrete without cold joint. This shows that cold joint with 240 minutes significantly affects the compressive strength value of concrete, especially when testing concrete at 28 days old. Horizontal direction testing produced smaller compressive strength compared to vertical direction testing.



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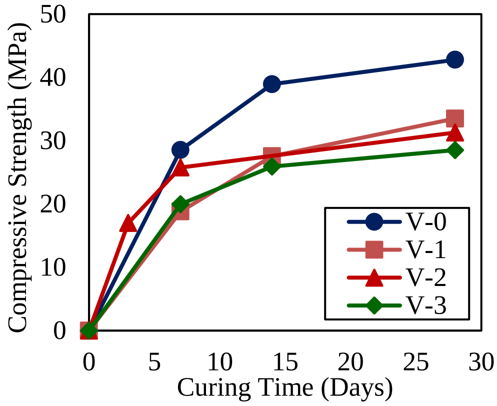
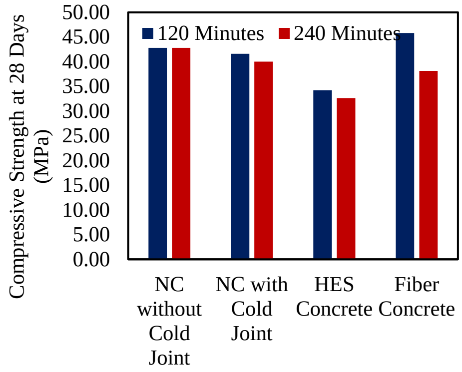


(b)

Fig. 4 Compressive strength with 240 minutes cold joint (a) Vertical direction (b) Horizontal direction

In Figure 5, it looks more clearly the results of the compressive strength test in the vertical and horizontal direction when the concrete was 28 days old. The compressive strength of concrete is always reduced when using a longer casting time. At the age of 28 days, Figure 5 (a) shows only the vertical direction fiber concrete (V-3) test, which produces higher compressive strength than normal concrete without cold joint (V-0), while other types of concrete (V-1 and V-2) produce compressive strength smaller than normal concrete without cold joint. Fig. 5 (b) is the result of a horizontal cold joint test (V-1; V-2; V3), showing that the compressive strength obtained is always smaller than concrete without cold joint (V-0). It can be concluded that cold joint greatly influences the yield of compressive strength in concrete, so that special reinforcement is needed because it can increase the compressive strength of concrete. The use of fiber in concrete is also not effective enough in structures with horizontal joint cold joints.



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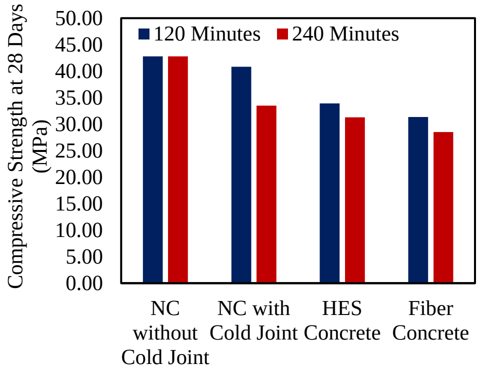

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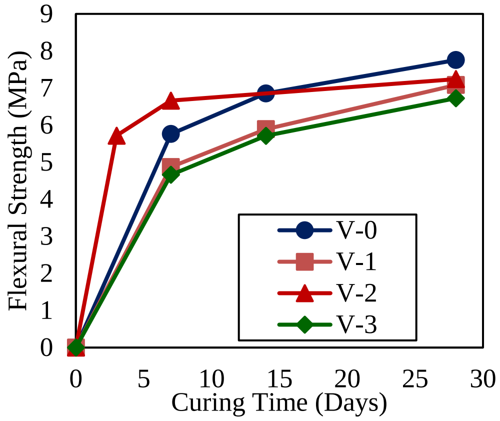
Fig. 5 Compressive strength at 28 days (a) Vertical direction (b) Horizontal direction

3.3 Flexural Strength

Flexural strength testing was conducted on concrete, aged 3, 7 and 28 days for concrete with superplasticizer added ingredients, while in normal concrete and fiber concrete, it was tested at ages 7, 14 and 28 days. This flexural strength test did not use reinforcement. This test will only display the maximum value of flexural strength produced. Figure 6 shows the results of a concrete flexural strength test with a casting interval of 120 minutes. In flexural testing, Figure 6 (a) shows the test results that concrete with high initial strength works quite effectively because it produces a relatively good flexural strength at its initial age compared to other types of concrete. However, the flexural strength test of 28 days shows that all concrete produces flexural strength that is no better than concrete without cold joint.

Figure 6 (b) produces flexural strength by testing the horizontal direction. In this result, it can be concluded that the superplasticizer strength used is good enough for high initial strength, but when the concrete was 28 days old, the flexural strength produced was almost the same as normal concrete without cold joint. The horizontal direction test showed that the cold joint direction does not affect concrete flexural strength value, especially in cold joint concrete with a casting range of only 120 minutes. At casting intervals that do not exceed 120 minutes, it is better to consider the effect of the load in the direction of the cold joint but can ignore the load that is perpendicular to the cold joint. This refers to the test results in Figure 6, which shows the directional loading of the cold joint affects the flexural strength, while the loading in the opposite direction to the cold joint did not significantly affect the flexural strength.



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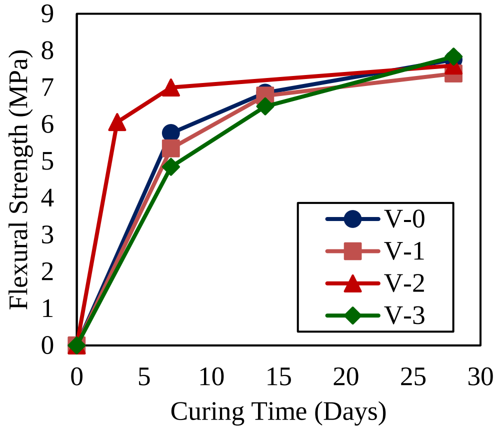
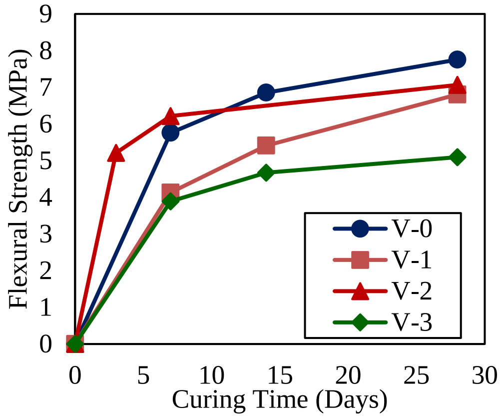


(b)

Fig. 6 Flexural strength with 120 minutes cold joint (a) Vertical direction (b) Horizontal direction

Flexural strength testing with 240 minutes of casting pause was also carried out, as shown in Figure 7. The results showed that both vertical and horizontal testing obtained lower flexural strength values compared to concrete without cold joint. Decreasing the value of flexural strength positively affects the concrete's capacity if the casting on the structure is carried out in stages exceeding 240 minutes, so it is necessary to consider the casting pause time to ensure no reduction in the structure's strength in the long run.



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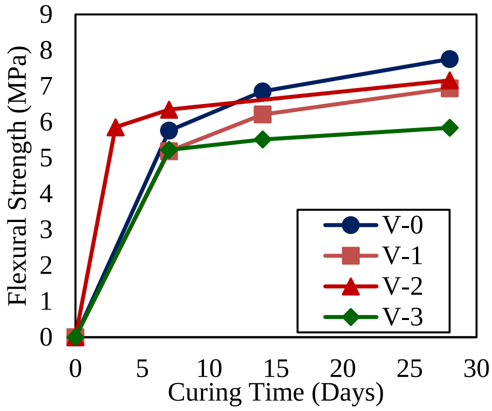

(b)

Fig. 7 Flexural strength with 240 minutes cold joint (a) Vertical direction (b) Horizontal direction

Figure 8 is the result of the flexural strength test on 28 days of concrete. The results show that the flexural strength of concrete has decreased due to the cold joint both by testing the vertical and horizontal directions. Figure 8 (a) results from the flexural strength test with vertical or directional test direction with the cold joint. The results show that at the age of 28 days, testing in this direction helped reduce the capacity of concrete to withstand loads, especially bending loads. Besides, this test shows that the longer the casting pause is, the smaller the flexural strength value. Figure 8 (b) is a horizontal direction test or load applied in the opposite direction to the cold joint.

Figure 8 (b) shows the results with a casting interval of 120 minutes. The flexural strength obtained was not too different from the flexural strength of normal concrete without using a cold joint. Whereas concrete with 240 minutes casting gap experienced a significant decrease in flexural strength. It can be concluded that the casting interval with more than 240 minutes will affect the flexural strength value of the concrete, especially for concrete with a test life of 28 days.

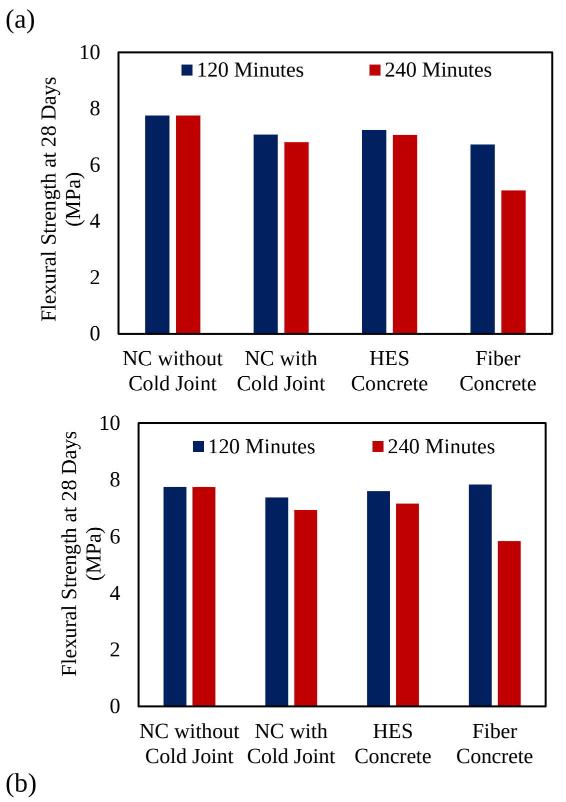

Fig. 8 Flexural strength at 28 days (a) Vertical direction (b) Horizontal direction

Figure 9 is a sample of specimens before and after testing. Cracks or failures that occur as a whole occur in the middle of the span, or structural failure that occurs is a bending failure. This is because concrete used without bridging, and the load is given during testing is a one-point load in the center of the span. Overall, this shows that the use of fiber in concrete can increase the compressive strength of concrete with cold joint, especially in directional testing with the cold joint.

However, the results of other tests show that the casting interval of 240 minutes is sufficient to affect the compressive strength and flexural strength of the concrete. Therefore, casting with a gap of 240 minutes needs to be avoided in construction projects because it will reduce the value of the durability of the concrete and reduce the service life of the structure in the future. There is also a need to do more in-depth research on the permeability or absorption level of concrete that experiences 0 minutes of the cold joint because it is feared that it will be straightforward to absorb water and cause corrosion on structures to use a reinforcement system. Besides, it is necessary to pay attention to the initial setting time and final setting time before carrying out the casting because using different materials or different added materials will produce different final setting times.

This study uses superplasticizer added ingredients for high initial compressive strength to experience a hardening process faster than other concrete. In compressive strength and flexural strength testing, concrete using superplasticizer added to be lower when the concrete is 28 days old.

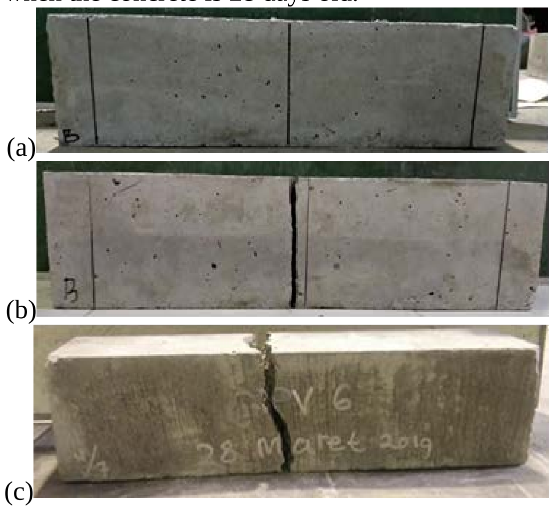

Fig. 9 (a) Specimens before the test; (b) normal concrete without cold joint after test V-0) ; (c) fiber concrete after the test (V-3)

4. CONCLUSION

Based on the compressive strength and flexural strength results, the casting pause time is very influential. The longer the casting pause time used, the lower compressive strength and flexural strength values. The addition of a superplasticizer for high initial strength in concrete is only practical for its initial age, especially in flexural testing. The utilization of a superplasticizer on concrete causes the final setting time to be shorter so that the concrete hardens faster. This causes concrete strength with the cold joint is significantly reduced because the first stage concrete has hardened first before casting the next layer. The use of fiber in concrete is quite effective in cold joints with directional loading to the cold joint, but the fiber does not work well with loading opposite the cold joint. This is because the fiber serves as a drag on the tensile force, not to hold the compressive force on the concrete.

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