The study of laminate concrete between geopolymer and conventional

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Abstract. Lamination method on concrete is the combination of two different kinds of concrete namely conventional concrete made of cement as binder and geopolymer concrete by using fly ash. This combination aims to know the setting time happened in the conventional paste as well as the geopolymer paste with similar fas percentage and to obtain the comparison of the compressive strength point of the concrete by using similar mixed design concept. In this study, the variation of the specimens consist of full conventional concrete, full geopolymer concrete, laminated concrete A, laminate concrete B, and laminate concrete C. Based on the result of the study, it can be seen that the concrete was always increase along with the increasing age of the concrete. The higher compressive strength from the five variations of the specimen were on full geopolymer concrete with 362.96 kg/cm\textsuperscript{2} as the compressive strength point and the increasing percentage in 14 days was 30.71 \% and for 28 days was 47.59\%. While on the laminate concrete, the highest compressive strength was on laminate concrete B with the arrangement method of half conventional method and half geopolymer concrete with vertical concrete position. The compressive strength point of the laminate concrete B was 268.15 kg/cm\textsuperscript{2}, while for full conventional concrete was 202.96 kg/cm\textsuperscript{2}. This conventional concrete was on the fourth composition after full geopolymer concrete, laminate concrete B, and laminate concrete A.

1. Introduction

Portland cement is one of the most widely concrete materials used in the civil engineering construction. According to[1][2] cement has a disadvantage that is not environmentally friendly due to carbon dioxide gas produced effecting the increase of global warming. It was noted that per ton of cement produced an average of 0.77 ton of CO\textsubscript{2} from calcinations process, fuel combustion, and electricity consumption by chemical reaction. The estimation of cement production in the world will continually increase in every year. It can be seen in 1995 where the production of cement reached 1.5 billion ton and the production of cement in 2010 reached 2.2 billion ton[3]. One of the latest research studies mentioned the existence of fly ash as a substitute for binder on concrete. Fly ash or commonly referred to fly ash is a waste of PLTU (electric steam power plant) from coal combustion in the form of fine particles. Fly ash is used as material in making geopolymer concrete. The geopolymer concrete is environmentally friendly concrete consists of crushed stones as coarse aggregate, sand as fine aggregate, and fly ash used as binder and alkaline activator consists of combination of water and NaOH crystal and Na\textsubscript{2}SiO\textsubscript{3} as material composition of the concrete [2][4]
In the research conducted by [1], the geopolymer concrete has several advantages such as environmentally friendly because it does not radiate CO$_2$ gas into the air, the compressive strength of concrete can achieve 70% in the first four hours, has a fixed volume, and resistant to aggressive environments. The geopolymer concrete also has disadvantages despite its advantages that is in the study conducted by [5] mentioned that the geopolymer concrete has a lower strain that is equal to 29.03% by using curing oven, while for wet sack curing has a strain equals to 27.69% which is lower when compared to the conventional concrete, so it can be concluded that the geopolymer concrete is more brittle than the conventional concrete. In this study, the method used to reduce the brittle properties of the geopolymer concrete is by using lamination method. The lamination method on concrete is a way of combining two different types of concrete. The combinations made in this research are the conventional concrete made of cement as a binder and geopolymer concrete by using fly ash. The aim of this study is to know the characteristics of conventional, geopolymer, and laminate concrete with concrete compressive strength test conducted and to know how is crack patterns of laminate concrete by using different arrangement patterns due to the load that occurred.

2. Methodology

In this research, the specimen consists of five different concrete variations namely conventional, geopolymer, and laminate concrete with three kinds of arrangement patterns that vary [4]. The difference for this laminate concrete is based on the vertical and horizontal direction layer arrangement. The level arrangement is made two layers consist of the conventional concrete layer and the geopolymer concrete layer. The layers of each arrangement level have the same length and width of 7.5 cm and 15 cm. The type of arrangement patterns can be seen in the following directions:

Laminate A: The loading direction is vertical and the arrangement pattern is arranged horizontally by determining the level of the half-cubic layer containing conventional concrete on the bottom layer and the subsequent half layer containing geopolymer concrete on the top layer.

Laminate B: The loading direction is vertical and the arrangement pattern is arranged vertically by determining the half-cubic layer containing conventional concrete and the subsequent half layer containing geopolymer concrete.

Laminate C: The loading direction is vertical and the arrangement pattern is arranged horizontally by determining the level of the half-cubic layer containing geopolymer concrete on the bottom layer and the subsequent half layer containing conventional concrete on the top layer.

![Figure 1. The Arrangement Patterns of Laminate Concrete](image)

![Figure 2. Mixed Design of Conventional Concrete](image)
3. The Amount of Material in the Specimen
The amount of material is made based on the percentage that has been determined in the mixed design and the weight of the content is set in each ten samples equals to 8500 gram per sample cube. For more clear, it can be seen in the table 1 and 2 below:

Table 1. The Material Composition of Conventional Concrete

| Type of Testing   | Conventional (gram) | Sand  | Cement | Water | Gravel |
|-------------------|----------------------|-------|--------|-------|--------|
| Conventional Concrete | 22100               | 18445 | 11305  | 33150 |
| Laminate A        | 11050               | 9222.5| 5652.5 | 16575 |
| Laminate B        | 11050               | 9222.5| 5652.5 | 16575 |
| Laminate C        | 11050               | 9222.5| 5652.5 | 16575 |
| **Total**         | **55250**           | **46112.5** | **28262.5** | **82875** |

Table 2. The Material Composition of Geopolymer Concrete

| Type of Testing   | Geopolymer (gram) | Sand  | Fly Ash | NaOH  | Na₂SiO₃ | Gravel |
|-------------------|------------------|-------|---------|-------|---------|--------|
| Geopolymer Concrete | 22100             | 18445 | 3768.33 | 7536.67 | 33150  |
| Laminate A        | 11050             | 9222.5| 1884.17 | 3768.33 | 16575  |
| Laminate B        | 11050             | 9222.5| 1884.17 | 3768.33 | 16575  |
| Laminate C        | 11050             | 9222.5| 1884.17 | 3768.33 | 16575  |
| **Total**         | **55250**         | **46112.5** | **9420.83** | **18841.7** | **82875** |

Curing Concrete
Curing concrete is done by using wet sack method. The concrete that has been removed from the mold will be covered by using a sack that has been moistened with water in accordance to the age of the concrete that is 7 days, 14 days, and 28 days. This curing concrete aims to avoid the weather effect on the concrete hardening process and so as to the concrete does not evaporate which can affect the compressive strength of the concrete.

Figure 3. Mixed Design of Geopolymer Concrete

Figure 4. The Process of Curing Concrete
4. Result And Discussion

Geopolymer Paste

The result of the data indicate that the initial setting time [6] occurred in 274 minutes or 4.34 hours while for the final setting time occurred when the reduction indicated 0 mm and there is no trace of Vicat needle on the sample specimens. It is occurred in 510 minutes or 8.30 hours.

Conventional Paste

The result of the data show that the initial setting time occurred in 178 minutes or 2.58 hours while for the final setting time occurred when the reduction indicated 0 mm and there is no trace of Vicat needle on the sample specimens. It is occurred in 330 minutes or 5.30 hours.

The Testing Analysis of the Compressive Strength

The testing of concrete compressive strength aims to determine the magnitude of resistance in the five variations of the specimen so that it can be known the compression of the compressive strength produced[7]. From the resistance testing result on each specimen that obtained as a result of a working press load, so it can be calculated the amount of the compressive strength obtained by calculating the division between the maximum loads divided by the surface area of the specimen[8].

Table 4 below is a compressive strength test on the concrete that is classified based on the age of the concrete test and the variation of the test sample. The table described as follows:

| The Variations of Test Sample | Compressive Strength of Concrete (kg/cm²) |
|-------------------------------|-----------------------------------------|
|                               | 7 Days | 14 Days | 28 Days |
| Laminate A                    | 162.22 | 201.48  | 204.44  |
| Laminate B                    | 145.19 | 229.63  | 268.15  |
| Laminate C                    | 84.44  | 154.81  | 201.48  |
| Conventional                  | 130.37 | 155.56  | 202.96  |
| Geopolymer                    | 188.15 | 245.93  | 362.96  |

Based on the table above, the result of the concrete compressive strength was taken the average of the compressive strength to be compared to the age of the concrete in each test so it can be gotten in figure 6 about the graph of the compressive strength toward the age of the concrete as follows:

![Figure 5. The Graph of Compressive Strength Toward the Age of the Concrete](image)

In the figure 5, the compressive strength graph toward the age of the concrete above explained the result of the compressive strength testing of concrete in five samples of specimen with curing process.
of wet sack for about 7 days, 14 days, and 28 days can be gotten that the compressive strength increased along with the increasing of the age of the concrete. It can be seen that the higher compressive strength of the concrete occurred on the geopolymer concrete. In the graph, the ratio showed that the conventional concrete has lower compressive strength than the geopolymer concrete and the laminate concrete with arrangement method of A and B. The arrangement of the increasing constant concrete happened in 14 days and 28 days[7].

The geopolymer concrete is always significantly increased that was increase 30.71% in 14 days and 47.59% in 28 days. In addition, from the three methods of the laminate concrete with the higher compressive strength was in the concrete with half-cubic arrangement pattern contained conventional concrete and the subsequent half layer contained geopolymer concrete. The concrete of laminate method code B was 47.62% in 14 days from the compressive strength of the conventional concrete and the compressive strength attained 24.31% in 28 days which is higher than the laminate concrete. This is proved that the laminate method code B with the arrangement pattern of half conventional concrete vertically and half geopolymer concrete with vertical position was also more efficient in increasing the compressive strength if it is compared to full conventional concrete. In the full conventional concrete was increase in each age of concrete but it was not similar as full geopolymer concrete as well as laminate concrete B and laminate A. The increase on this full conventional concrete was about 19.32% in 7 days to 14 days, while 30.48% was in 14 days to 28 days.

**The Analysis of the Compressive Strength toward the Arrangement Pattern**

In figure 6 about the graph of the compressive strength toward the arrangement pattern can be seen that the higher compressive strength point was 362.96 kg/cm² on geopolymer concrete. The increasing percentage of geopolymer concrete was grow bigger along with the growing age of the concrete which is proved from 7 days to 14 days was 30.71% and increased again 47.59% in 14 days to 28 days. In the laminate concrete, the higher compressive strength was laminate B. The increase of the laminate concrete B was not happen as big as full geopolymer concrete, but always increase along with the increase of the age of the concrete[5]. The ratio for the increasing percentage of the laminate concrete can be analyzed that 30.14% of laminate concrete C was the biggest increasing percentage but 268.15 kg/cm² of laminate concrete B was the highest compressive strength point. While on the conventional concrete, the increasing percentage was 30.48%. It was exceed the increasing percentage of the laminate concrete B with the compressive strength point of conventional concrete was 202.96 kg/cm². For more clear, it can be seen in the following figure:

![Figure 6. The Graph of Compressive Strength toward the Arrangement Pattern](image)

**The Analysis of Crack Pattern**

The crack pattern is one of the most commonly recognizable crack parameters. This research will analyze the crack patterns that occur in the concrete that has been tested its compressive strength on
the whole concrete with the size of 15 cm x 15 cm x 15 cm by lamination as the method of drafting the concrete. This crack pattern analysis aims to find out how the crack patterns that occur in two different types of concrete is done by lamination or merging.

The crack pattern in the picture above was in 7 days testing which is showed that the three kinds of concrete above has been cracked and broke out in part of the concrete. The cracks on the concrete have begun with small cracks that are widening and breaking. The geopolymer concrete was broken, while on the conventional concrete was only cracked. This is happen because the geopolymer concrete has been solidified (full hardening) in 7 days, so if it is given load on the concrete, it will be broken. In the figure 8, the crack pattern produced was getting wider from the top to the bottom.

It can be seen from figure 7 that of the above three types of concrete, the geopolymer concrete was more brittle when compared to the conventional concrete because the geopolymer concrete was rapidly hardening so that the geopolymer concrete was visually very brittle than the conventional concrete, while the breaks that occurred in the conventional concrete looked bigger when compared to the age of 14 days. In addition, the worst damage occured in the laminate concrete C due to the increasing of the highest percentage was 30.14%. From the visible look on the three types of concrete, most ruptures occured on the back of the three types of concrete.

5. Conclusion
Based on the research that has been conducted, so it can be concluded as follows:

a. It was found that the geopolymer paste by using fly ash as the binder had longer setting time compared to the conventional paste by using cement as the binder in the test of geopolymervicat and conventional vicat. The time difference between the conventional and geopolymer paste was 96 minutes.

b. The compressive strength produced in the conventional, geopolymer, and laminate concrete by using curing process of wet sack for 7 days, 14 days, and 28 days found that the compressive strength increased along with the increasing age of the concrete.

c. Based on the concrete compressive strength test, the highest point of compressive strength was on full geopolymer concrete that was equal to 362.96 kg/cm², whereas the highest compressive strength of laminate concrete was on the laminate code B which is on the second position after the
geopolymer concrete with the compressive strength value of 268.15 kg/cm². While for full conventional concrete was on the fourth after full geopolymer concrete, laminate concrete B, and laminate concrete A with the compressive strength point equals to 202.96 kg/cm².

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