The Flexural Strength of Bacteria-Based Concrete for Sustainable Materials

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Keywords: Flexural Strength, Bacillus Megaterium, Fly Ash, Cracks.

Abstract: Concrete is the most popular material used in construction. In fact, concrete lies in its resistance to compressive forces. However, the drawback of the concrete materials is weak in tension. Because of its weakness, it can cause cracks in the concrete. One way to handle cracks in the concrete is to make bacteria-based concrete. In this research, the type of bacteria used in concrete mixing is Bacillus megaterium. The purpose of this research is to study the effect of *Bacillus megaterium* on the flexural strength of concrete. The bacteria proportions of 1% and 2%, which are adopted in this study, were combined with fly ash as an additive material. The specimens were casted into beam molds sized (500x100x100) mm and then tested under a three-point bending machine to observe its bending capacity. The flexural strength of bacteria-based concrete was observed for some periods, namely 14 days and 28 days. From this research, it can be concluded that the flexural strength of bacteria-based concrete was raised up to 14,64% compared to virgin concrete.

1 INTRODUCTION

In infrastructure, concrete structures are the most popular structures. The advantage of a concrete structure is its resistance to compressive forces. This material is widely used because of its strength and durability (Bashir et al., 2016). On the other hand, the weakness of the concrete structure is weak tension.

From this weakness, concrete is quite sensitive to cracking which can compromise the durability of the concrete structure as a whole (Luthfi Muhammad Mauludin & Rabczuk, 2021) so it can cause cracks in the concrete. Starting from a small crack, then it becomes a medium crack and finally into a large crack. If small cracks are not treated immediately, it will cause larger cracks so that it can trigger cavities that can make the reinforcing steel corrosive. If repairs are not immediately carried out, it will result in structural failure (collapse) and can also threaten human life.

Cracks in concrete must be carefully monitored and periodically repaired for ensuring durability and safety (Luthfi M. Mauludin et al., 2018). Small cracks (microcracks) such as the one in that develop in the concrete due to unbalanced (balanced) tensile forces. Therefore, there is a self-healing concrete technology with a mechanism to independently repair the cracked part without human intervention in its maintenance (Mauludin et al., 2018).The crack trajectory is highly dependent on the inclusions in the material (Luthfi Muhammad Mauludin & Rendragraha, 2022). Because of that, the maintenance and repairs on concrete structures are needed periodically according to their needs and conditions. Meanwhile, the cost of maintaining and repairing concrete structures is quite high, Especially the crack that is located in difficult area, such as in water or on the ground.

To solve this problem, bacteria-based concrete is an alternative to many other conventional technologies because they are environmentally friendly, and have the ability to act as self-healing agents (Tiwary, 2021). The active bacterial cells able to convert the calcium lactate (CaC6H10O6) into CaCO3 (Calcium Carbonate) using oxygen and water (Tziviloglou et al., 2016).

In this study, a test will be carried out in the form of the application of *Bacillus megaterium* bacteria and calcium lactate which is inserted into the concrete mixture.

Savira, M., Ruslan, U., Keryanti, . and Mauludin, L.
The Flexural Strength of Bacteria-Based Concrete for Sustainable Materials.
DOI: 10.5220/0011982900003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 986-991
ISBN: 978-989-758-619-4; ISSN: 2975-8246

2 LITERATURE REVIEW

Bacterial Concrete or Bacterial-Based Concrete is intelligent concrete that exhibits human-like self-healing characteristics that increase the strength of the structure, especially under stress, and other advantages such as the overall service life of the structure were found to be increased, the effective utilization of bacteria from corrosion, due to the presence of water vapor generated used as a catalyst to continuously maintain the quality of concrete, self-healing concrete is better than traditional concrete because of its environmentally friendly nature (Ghodke & Mote, 2018).

Some researchers have conducted several methods of self-healing concrete with using many healing agents. Namely as follows.

a. Mauludin et al., 2018 in a journal article entitled Computational modeling of fracture in encapsulation-based self-healing concrete using cohesive elements examined self-healing concrete using computational methods carried out with Abaqus, Python and Matlab software.
b. Rahmawan et al., 2021, in his journal entitled Application of Bacteria as Self-Healing Agents in Concrete, discuss the comparison of various types of bacteria.
c. Gruyaert et al., 2016, in their journal entitled Capsules with evolving brittleness to resist the preparation of self-healing concrete. This journal discusses the types of capsule shells. Using polymer type capsules.

In previous studies, tests have been carried out using encapsulated techniques both computationally and experimentally, then there are studies using the overall base material in the form of geopolymers and there are studies that focus on the levels of Bacillus megaterium bacteria which are effective for increasing the compressive strength of concrete.

3 MATERIALS

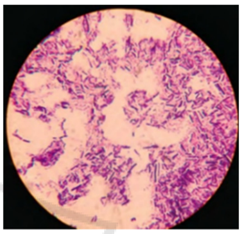
3.1 Bacteria

The type of bacteria used in this research is namely *Bacillus megaterium*. *Bacillus* bacteria can produce as fillers for binding materials to shrink the capillary pores of concrete to increase its strength and durability (Andalib et al., 2016).

Bacillus megaterium is an organism that has following characteristics: not filamentous, gram positive, rod-shaped, produces endospores, catalase positive, aerobic, nitrite negative and VP negative.

This kind of bacteris have endospore in the middle of its cell. Bacillus bacteria have a positive effect on the compressive strength of concrete and flexural strength compared to conventional samples, and can reduce water absorption (permeability) (Stanaszek-Tomal, 2020).

The following is the classification of Bacillus megaterium as listed in Figure 1:
Kingdom : Bacteria
Filum : Firmicutes
Kelas : Bacilli
Ordo : Bacillales
Famili : Bacillaceae
Genus : Bacillus
Spesies : Bacillus megaterium



Source: (Jayanti rusyda, 2014)

Figure 1: Bacillus megaterium Bacteria.

3.2 Fly Ash

Fly ash is used to stabilize the temperature of cement so as not to harm the microbes inside. This type of geopolymer has several advantages: more environmentally friendly (in the manufacturing process without releasing CO_2 emissions into the atmosphere), high workability (easy to flow or self-leveling), more resistant to chemical attack (sulphate, acid, and chloride), and more resistant to high temperatures. Therefore, other substances are needed such as Sodium Hydroxide (NaOH) and Sodium Silica (Na_2SiO_3) (Rizal et al., 2020).

The type of fly ash is grade 6 or class F which is an active type of fly ash, it can be used as a binder not only as a filler as listed in Figure 1.

4 METHODOLOGY

To carry out this research, good planning is needed so that in its implementation it can run effectively and efficiently. The type of this reasearch is experimental.

Figure 2: Fly Ash.

The reseacrh was begun with studying the previous studies on bacteria-based concrete. The design the concrete with f'c 20 MPa specification, was used ACI 211.1-1991 standard for 36 speciments.

The next step is testing the concrete materials. The tests are Cement Specific Gravity (SNI 1527-2531-1991), Cement Grain Fineness (SNI 03-1969/1970 – ASTM C.127/128-95), Coarse Aggregate Gradation Testing (SNI 03-1968-1990/ BS 410-1986), Aggregate Moisture Testing (SNI-03-1971-1990), Sludge Content Testing Passed through Sieve 200 (SNI 03-4142-1996/ ASTM C.117-95), and Organic Fine Aggregate Testing (ASTM C.33-95).

Figure 3: The Preparation of Concrete Materials

After the materials test and mix design had been done, the next step are preparation of the bacteria, concrete materials as listed in Figure 3 and making the speciments.

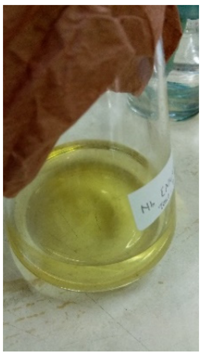


Figure 4: Bacteria Sample.

After prepared the media (nutrient agar) was prepared with using autoclaved at 120°C for 15 minutes, then the media kept in the incubator at 35°C and the colony of bacteria will growing there. After 3 days, the colony of bacteria will be moved into a nutrient broth then shaked in 5 days along as listed in Figure 4.

Figure 5: Concrete Casting Process.

To perform the flexural strength test, the bacterial sample mixed with the concrete. When bacterial concrete was casted, bacteria sample was added to the water in ratio 1:100 (1% proportion) and 2:100 (2% proportion). To cast the virgin concrete (conventional concrete), no bacteria was added and no other treatment was applied. The concrete casting process is as listed in Figure 5.

Figure 6: The Bending Machine.

To do Flexural Strength Test, he standard that used in this test is ASTM C.293. Flexural strength test was performed on beam of size 100 mm × 100 mm × 500 mm with three point bending. The testing was conduct in 14 days and 28 days. Then tested under three point bending machine as listed in Figure 6.

5 RESULT AND DISCUSSION

The following are the result of flexural strength in 14, and 28 days, flexural strength values of virgin concrete, Bacteria-based concrete (BBC) which proportion are 1% and 2%, concrete with fly ash 2%, then Bacteria-based Concrete with fly ash 2% containing 1% and 2% bacteria proportions were tested.

5.1 The Effect of Bacteria in Conventional Concrete

After tested in 14 dyas of the specimens, there are a trend increasing between the bacteria based-concrete and virgin concrete the virgin concrete, concrete with bacteria-based concrete 1% and bacteria-based concrete 2% were tested and the result is increased between the virgin concrete and the bacteria-based concrete 2% as listed in Figure 7. The increasing is up to 14,64%.

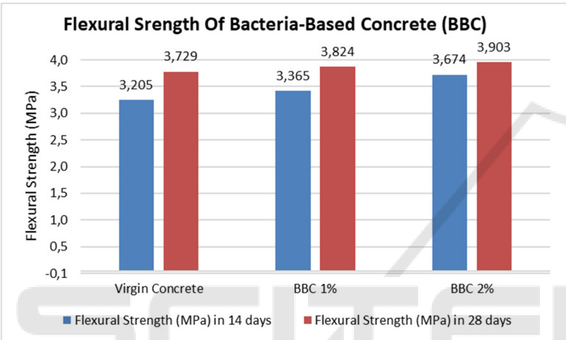


Figure 7: Graph Showing The Flexural Strength in 14 and 28 Days.

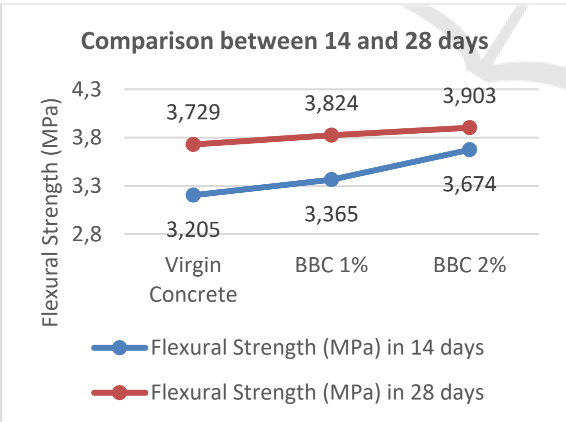


Figure 8: Graph Showing The Comparing Flexural Strength in 14 and 28 Days.

Then, after 28 days, the virgin concrete, concrete with fly ash 2%, bacteria-based concrete 1% and bacteria-based concrete 2% were tested and the result is increased between the virgin concrete and the bacteria-based concrete 2% as listed in Figure 7. The increasing is up to 4,44 for BBC 2 % and 4,64 for BCC 1% compared with the virgin concrete as liested in Figure 7.

So, the comparison between the 14 and 28 is listed in . It shows that the result of an increasing trend of bacteria-based concrete with a significant increase between the virgin and the bacteris-based concrete which bacteria proportion that the highest flexural strength is 2% bacteria proportion.

5.2 The Effect of Bacteria in Fly Ash Concrete

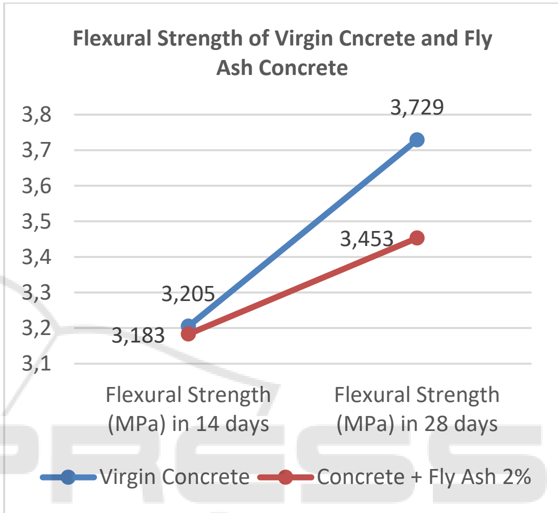


Figure 9: Graph Showing The Comparing Flexural Strength of Virgin Concrete and Fly Ash Concrete in 14 and 28 Days.

Then, after 28 days, the virgin concrete, concrete with fly ash 2%, bacteria-based concrete 1% and bacteria-based concrete 2% were tested. And the Figure 9 shows that adding a fly ash in 2% could not increase the flexural strength of virgin concrete.

The flexural test result in 14 days as listed in Figure 10, is increased between the concrete + Fly Ash 2% and the bacteria-based concrete 2%. The increasing is up to 10,54% for BBC 2 % and for BCC 1%, there was degression into 8,13% compared with the concrete+ Fly Ash 2%.

The following is the flexural result of adding 2% fly ash into bacteria-based concrete 1% and bacteria-based concrete 2% in 28 days as listed in Figure 10. The comparison between 1% and 2% bacteria proportion in 28 days was variated degression between the concrete + Fly Ash 2%. For the BBC 1%+Fly Ash 2% the degression was 7,79% and for the BBC 2%+Fly Ash 2% the degression was 7,79% compared with the concrete + Fly Ash 2%.

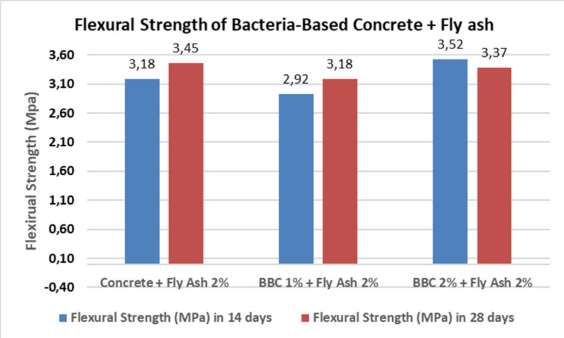


Figure 10: Graph Showing The Flexural Strength of fly ash 2% concrete, fly ash 2% + bacteria 1% concrete , and fly ash 2% + bacteria 2% concrete in 28 Days.

5.2 The Specimens After Flexural Strength in 14 Days and 28 Days

The following are the condition of specimens after flexural strength test as listed to Figure 11 and Figure 12.

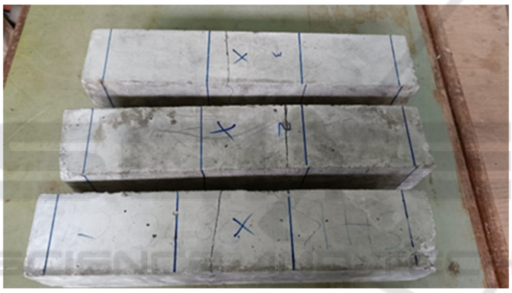


Figure 11: The Specimens After Flexural Strength Testing Conditiosns.

Figure 12: The Crack Pattern of Specimens After Flexural Testing.

6 CONCLUSION

The goal of this research was to see how bacteria (Bacillus megaterium) affected the flexural strength, of conventional (virgin concrete) and bacteria-based concrete. The results of this study can be concluded as follows:

- Based on the test results, this bacteria-based cocrete is a promosing material, by using bacteria-based concrete could reduce to use cement materials and forthemore it will be a sustanable materials.
- The concrete samples were evaluated for flexural strength in both conventional and bacterial concrete. By applicated the bacteria in concrte, it was positively affected to increase the flexural strength compared with the virgin concrete. The higher the proportion of bacteria, it can make the higher flexural strength. In comparison to ordinary concrete, the flexural strength of bacillus megaterium as bacteria-based concrete by 14,64% while the fexural sstrength of adding fly ash 2% is 8,91%.
- By adding fly ash 2% and tested in 14 and 28 days, it doesn't shows that the result is increased the mechanical properties compared with the fly ash concrete + bacteria. Due to the fly ash as an additive could make another condition of bacteria, so it could not be affected for the flexural strength.

ACKNOWLEDGEMENTS

This research was funded by Politeknik Negeri Bandung (POLBAN) through Post Graduate Research Grant Program (PPS) in 2022.

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