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The Effect of Bacteria in Thermal Comfort in Building: A Systematic Review

Sharifuddin Aisa Ahmad[1], Mohd Irwan Juki[2]*

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

[2]Jamilus Research Centre, Faculty of Civil Engineering and Built Environment
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: Bacteria is widely used in concrete as self-healing agent this is called bio-concrete, this production might affect the thermal comfort in the building. The research goals are to determine the impact of bacteria on thermal comfort in a building as well as to discover the elements that influence thermal comfort in a structure. Surprisingly, the results of the comparison revealed that the presence of bacteria in concrete might increase the compressive strength of concrete as well as its durability. The researchers choose the most appropriate species of bacteria to be employed, as well as the compressive strength, from a survey of bacteria that have previously been used successfully. Based on the comparison of the compressive strength of concrete employing various types of bacteria, as well as the analysis of thermal comfort from earlier studies, the specifics of the conclusion and debate were developed in more depth. The findings of this study reveal that the various types of bacteria used in concrete have distinct effects on the concrete, which may lead to an increase in the compressive strength of concrete as well as the durability of the concrete. It has been shown that the bacteria-contaminated concrete has a modest increase in compressive strength, and that bacteria is not one of the factors that impact the thermal comfort of a building.

Keywords: Bacteria, Thermal Comfort, Compressive Strength

1. Introduction

Clay is the most common material used to make bricks, but calcium-silicate and concrete are also commonly used to make bricks. Bricks are minimal rectangular squares that can be used to construct different segment of a structures, most regularly dividers. They are still used because they are conservative and simple to work with, can be very strong under pressure, are long-lasting and low-

*Corresponding author: irwan@uthm.edu.my

maintenance, can be combined into complicated designs, and are aesthetically pleasing on the outside [1].

Nowadays in warm and moist environments thermal comfort can turn into an issue to the tenants of numerous residential buildings and make discomfort of the occupants. The state of mind that reflects fulfilment with the warm climate is known as thermal comfort [2]. The increase in temperature can make discomfort to the occupants.

Researchers have devised a novel way for improving the properties of concrete, specifically the ability to self-heal fractures. This new method is a biological approach by using bacteria in the concrete mixtures. Apart from dissolving calcite particles in the mortar matrix, crack-penetrating water would also react with ambient carbon dioxide to form partially hydrated lime components such as calcium oxide and calcium hydroxide, which are not fully hydrated lime components.

2. Methodology of Study

In a systematic review, a flow chart is utilised to depict the process and suitable flow, as seen in Figure 1. This approach will assist in explaining whether a microorganism has an impact on the thermal comfort of a building by using the suitable technique. A research methodology system is essentially a collection of methodologies or procedures for doing research. It is also known as the research phase or the method cycle. A concept may be approached using a variety of techniques, each of which can be applied to distinct parts of the methodology. The systematic review was led in two distributers to be specific Google Scholar and Science Direct. The goal of this systematic review thesis is to create an opinion based on the scientific information available to enhance clinical decision-making[3]. This study methodology was mostly based on Google Scholar. Google Scholar is one of the platforms that caters to the research information needs of academics, administrators, students, and librarians all around the world.

There are four steps to follow for the limitation of the articles that are going to be used for this research. The first step is to search for at the databased using the main keyword for this research. Then, identify the article by the year limitation, the period of year being used is between 2011-2021. The second step is the article is selected based on the titles related to the research. Step three, the full text article is chosen based on step before. Step four involves reading the full article that was chosen, and the case studies were chosen based on the validity of the study data and their ability to make a clear contribution. The step is shown in Figure 2.

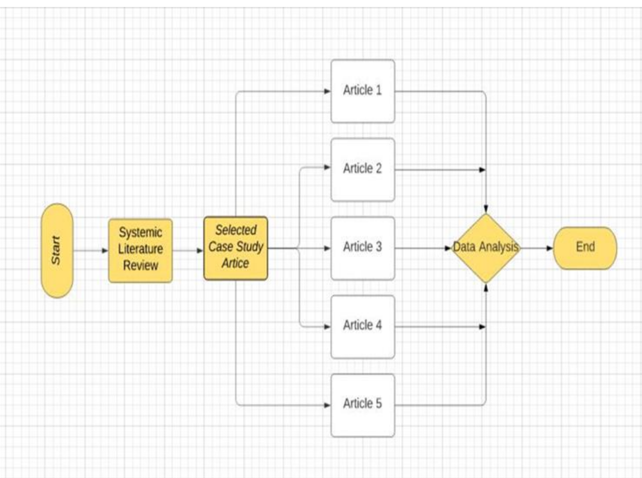


Figure 1: Workflow of Methodology

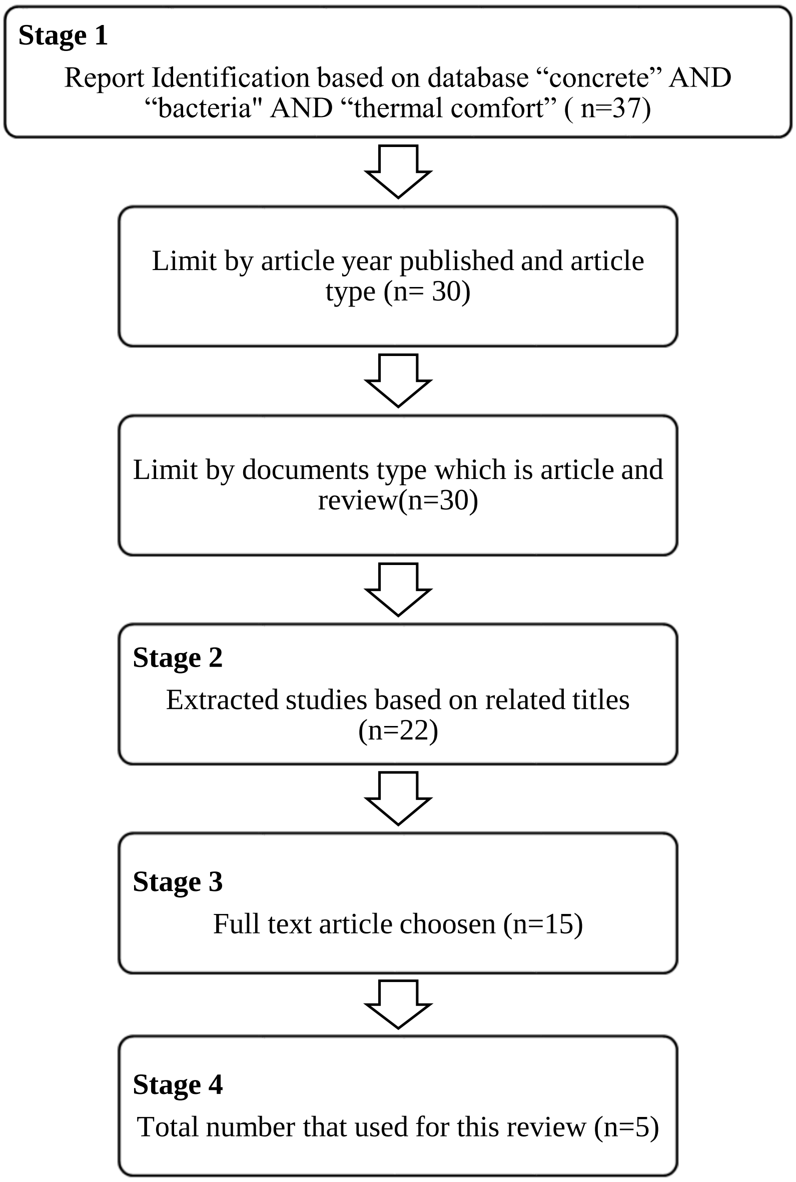


Figure 2: Step of Review Protocol

3. Results and Discussion

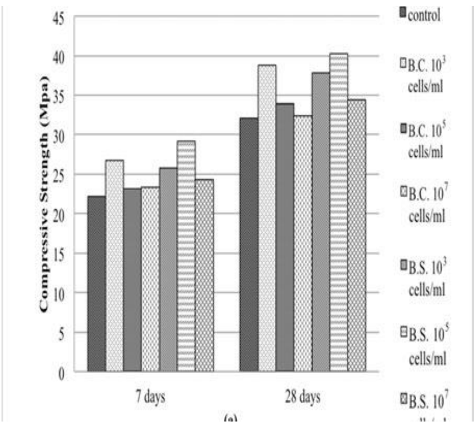
The experimental investigation is being carried out by several different scientists. The information acquired on the numerous types of bacteria that were employed was evaluated, and a subsequent dialogue took place. The parameters that influence thermal comfort as well as the comparison of compressive strength by utilising various types of bacteria will be discussed in more depth in the following sections.

3.1 Analyzation of compressive strength by using bacteria

It has been shown that there was an increase in compressive strength at both the 7-day and the 28-day time points. It was discovered that the optimal focus differed depending on the bacterium studied. Bacillus Subtilis and Bacillus Cereus were shown to have optimal groupings of 10^5cells/ml and 10^3 cells/ml respectively. Additionally, the growth of Bacillus Subtilis at optimum fixation resulted in greater compressive strength as compared to the instances obtained with each of the three convergences of Bacillus Cereus at both 7 days and 28 days [4].

Bacteria were shown to be effective in repairing minor cracks in cement, according to several research. he bacterium's precipitation of Calcite ($CaCO_3$) creates spaces between concrete grids, which results in a denser cement as a result. The potential of bacteria to operate as a self-healing specialist in concrete has shown to be a promising arrangement in the laboratory.

The results shown in Figure 3 demonstrated that the use of those bacteria resulted in an increase in the overall compressive strength of cement, both at 7 days and at 28 days after the start of the experiment. It has been discovered that the perfect fixation Bacillus Cereus concentration was 10^3 cells/ml, but the appropriate focus for Bacillus Subtilis was 10^5cells/ml [5]. When comparing the bacterium Bacillus Cereus to the control concrete at the optimal focus, the expansion in compressive strength was about 20% at both 7 days and 28 days for both 7 and 28 days. Again, the expansion in compressive strength was observed for Bacillus Subtilis at 7 days and 28 days when compared to the control concrete, with 32 percent and 25 percent, respectively, at 7 days and 28 days. Figure 4 depicts the increase in compressive strength achieved with the use of two different types of microorganisms.



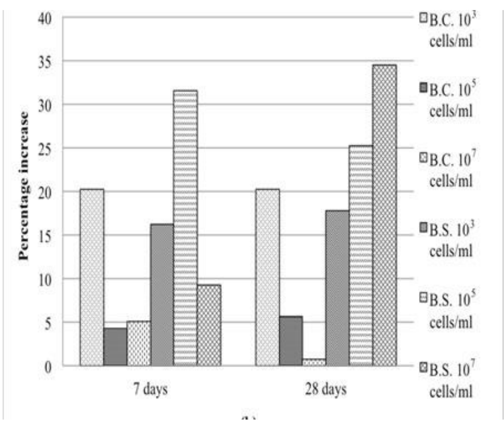


Figure 3: Compressive strength test result[5] **Figure 4: Percentage increase in compressive strength[5]**

Considering that specific fungi and bacteria have a local capacity of $CaCO_3$ creating biomineralization they are thought of to be productive strengthening or self-healing agents and this has brought about the improvement of utilizations wherein microbial cells and nutrients are added to the concrete mix before its utilization, as a counteraction measure [6].

3.2 Analyzation of Factor That Affect the Thermal Comfort

In the context of a warm environment, thermal comfort refers to the state of mind that expresses contentment, and it is measured using an abstract evaluation. The human body may be thought of as a heat engine, with food serving as the source of energy. They are six essential factors that directly influence thermal comfort and can be classified into two classifications individual elements because they are personal factors and environmental elements because they are states of the thermal environment. In addition to metabolic rate and cloth level, the following options are available air temperature, mean radiant temperature, air speed, and humidity.

3.2.1 Humidity

The amount of moisture in the air is referred to as humidity. Excessively high or too low levels of dampness may cause discomfort in some people. The percentage between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can contain at that temperature is known as relative humidity. The greater the relative humidity in the air, the more difficult it is to perspire because wetness prevents perspiration from dissipating from the skin.

Relative humidity of 70% or more forestalls our body sweat from getting vanished in the air and the maintenance of the perspiration on the body surface will prompt more noteworthy thermal discomfort [7]. Assuming that the individual is near a radiant heat source, this will likewise drastically build the heat stress. This phenomenon is for the most part known as radiant temperature.

3.2.2 Air Velocity

One of the main elements according to thermal comfort since individuals are sensitive to air development designs. Air speed is the speed at which air gets across an individual for example cooler air moving at a quicker rate might chill a laborer off, while still, warmed air might cause individuals to feel stodgy. Similarly significant is the way that air causes draughts assuming the air temperature is not as much as skin temperature, it will expand heat loss through the skin, in any event, when the system is in heat mode [8].

3.2.3 Air Temperature

The temperature of the air encompassing your body. Climatic temperature or air temperature will conclude how hot or cold we feel. Assuming that the air is cooler than the external air and assuming it moves or courses at an impressive speed, this will bring about more heat reduction.

3.2.4 Radiant Temperature

Thermal radiation is the heat that radiates from a hot object or surface. If there are heat sources present in a climate, it is possible that radiant heat will be accessible. It is the radiant temperature that has a greater influence on how we lose or receive heat from the environment than it is the air temperature. Radiant temperature is the warmth that radiates from a heated object, such as the sun, radiators, hot surfaces, and hardware, to the surrounding environment.

3.2.5 Clothing Level

The amount of insulation provided by clothing is measured in degrees Celsius. Increased amounts of clothing will reduce the amount of heat lost via the skin and decrease the temperature considered to be comfortable in the surroundings. Wearing a lot of apparel or PPE will make you too hot, wearing dress with lacking protection in colder temperatures will make you excessively cold. Accordingly, apparel can both reason and control thermal comfort.

3.2.6 Metabolic Heat

In other words, the more real labour we accomplish, the more hotness we generate. The more heat we generate, the greater the amount of heat that needs be released to avoid overheating. The relationship between metabolic rate and thermal comfort is crucial. Individual actual quality should always take precedence over all other considerations when considering their thermal comfort because factors such as their size and weight, age, health status, and gender can all have an impact on how they feel, regardless of whether different factors are considered in different ways. [9].

3.3 Effect of Using Bacteria in Concrete

Crack and gap remediation using Microbiologically Induced Calcite (MICP) or Carbonate Precipitation (CaCO3) is an innovative method that falls under a more comprehensive classification of science known as biomineralization. Microbiologically Induced Calcite (MICP) or Carbonate Precipitation (CaCO3) is an innovative method that is embraced in the remediation of cracks and gaps in calcium concrete. In addition, MICP is particularly favourable since the Calcite precipitation induced by bacterial activity is free of pollution and occurs in a natural environment. The approach may be used to test the compressive strength and solidity of fractures in concrete specimens, among other things [10].

When non-responded limestone and a calcium-based nutrient are combined with the aid of bacteria, self-healing concrete is created. Self-healing concrete is used to repair fractures that have appeared in a building. Bacillus bacteria, a rare and exceptional kind of bacteria, are used in conjunction with a calcium supplement known as Calcium Lactate. In addition, since the bacteria use oxygen to transform calcium into limestone, this cycle aids in the prediction of steel erosion due to cracks by reducing the amount of oxygen available for bacteria to consume. Specifically, it focuses on the structural strength of steel reinforced concrete structures.

3.4 **Comparison of The Effect of Bacteria on Concrete**

Comparison is made from the previous result on different researchers due to bacteria effect on concrete each article shows a particular result. This happened because the researcher in every article uses bacteria as a different purpose. Based on table 1 shows the difference of uses of bacteria from all papers.

Table 1: Element used for each article

Author	Type of bacteria used	Uses of bacteria	Duration (Days)
[11]	Sporoscarcina pasteurii	Enhanced compressive strength Reduced porosity and permeability	28
[12]	Bacillus subtilis	As a self-healing agent	28
[13]	Bacillus cohnii Bacillus halodurans Bacillus pseudofirmus	Mediate the production of mineral rapidly seal cracks Decrease concrete permeability Better protect embedded steel reinforcement from corrosion	28
[14]	Bacillus cereus Bacillus subtilis	Increase compressive strength As self-healing agent	28
[15]	Bacillus pasteurii Bacillus subtilis	Increase the strength and durability properties of concrete Reduces permeability and porosity Reduction in water absorption	28

From table 1, clearly showed that the bacteria have its own uses in concrete. The uses of bacteria can increase the compressive strength of the concrete such as sporoscarcina pasteurii. Bacillus cereus and Bacillus subtilis are used as a self-healing agent. The crack that occurs in the concrete can be healed by itself if the cracks is small. The uses of bacteria in the concrete can help strengthen the durability of the concrete. Bacteria can also decrease concrete permeability and reduced porosity in the concrete. Bacteria is often used in the concrete as it medium.

3.5 Comparison of the effect of compressive strength

Comparison is made from the previous result on different researchers because of compressive strength from each article shows a particular result. This happened because the researcher in every article uses bacteria as a different purpose. Based on table 2 shows the difference of uses of bacteria from all papers.

Table 2: Comparison of Compressive Strength

Author	Type of Bacteria Used	Compressive Strength
[11]	Sporoscarcina pasteurii	28Mpa
	Controlled concrete	24Mpa
[12]	Bacillus subtilis	29.43Mpa
	Controlled concrete	25.89Mpa
[13]	Bacillus pseudofirmus	55Mpa
	Controlled concrete	52Mpa
[14]	Bacillus cereus	32Mpa
	Bacillus subtilis	34Mpa
[15]	Bascillus pasteurii	35% more than control concrete
	Bacillus subtilis	12% more than control concrete

By comparing the compressive strength of the data, it was possible to identify the measurement of comparison. Table 2 shows the compressive strength of concrete with and without concrete for each of the products in the sample. From Table 2 clearly showed that concrete with bacteria has more compressive strength than the controlled concrete. Chahal, Siddique, & Rajor (2012) result in compressive strength is lowest from the other which is for the concrete with bacteria sporoscarcina pasteurii is 28Mpa while for the controlled concrete is 24Mpa. This improvement in compressive strength was because of deposition on the bacteria cell surfaces inside the pores. These bacteria can stay alive and develop inside concrete structures. Urease creating bacteria help in mineralization of calcium carbonate. It releases carbon dioxide from urea, which condenses with calcium particles and results in the deposition of calcium carbonate in the form of calcite on the surface of the water.

Result from Khaliq & Ehsan (2016) shown that the compressive strength of concrete made with bacteria Bascillus subtilis is 29.43Mpa greater than the compressive strength of controlled concrete, which is 25.89Mpa higher. This is since bio concrete is a product that includes the healing of cracks through the creation of mineral mixtures as a result of microbial action in concrete. Autonomous healing through this cycle increments the structural durability through decrease in concrete cracks.

The result from De Belie et al (2018) shows that the controlled concrete is less than the concrete using bacteria that is 52Mpa and 55Mpa. Bacteria intercede the development of mineral which quickly seal newly cracks, a process that correspondingly decrease concrete permeability, accordingly better shield embedded steel support from corrosion.

For Mondal, Das, & Kumar Chakraborty (2017) result shows that concrete using bacillus subtilis is higher than the concrete use bacillus cereus as bacteria that is 34Mpa and 32Mpa. Vacancies between concrete matrixes are created by calcite precipitation caused by a bacterium, which results in a denser concrete as a result.

Result obtains from Vijay, Murmu, & Deo (2017) shows that concrete using bacteria that is bascillus pasteurii and bascillus subtilis is higher than the controlled concrete. The compressive strength for concrete using bascillus pasteurii is 35% more than the controlled concrete meanwhile for concrete using bascillus subtilis is 12% more than the controlled concrete. Bio-mineralization procedures give promising outcomes in fixing the miniature cracks in concrete.

3.6 Analyzation of thermal comfort for all articles

The quality of indoor air (IAQ) has the potential to influence human welfare and thermal comfort. The nature of the living climate is determined by the structure of the building, and thermal comfort and the well-being of the inhabitants are vital indicators of its success. In the interior environment, the ventilation system plays an important role in improving indoor air quality (IAQ) and reducing tenant annoyance. Their goal is to remove airborne contaminants while also weakening their ability to concentrate to an acceptable degree. The indoor regulator is the primary control mechanism for guaranteeing thermal comfort in many buildings. It only monitors tolerable air temperature and ignores other environmental parameters such as humidity, impurity fixations, velocity, and other environmental factors [16].

Several environmental and individual elements, both concrete and abstract, have an influence on thermal comfort, including air temperature, the temperature of surrounding surfaces, the air development, the relative stickiness, and the rate of air exchange [17]. It has been discovered that indoor habitat can harbour microbial taxa that are not commonly found outside, and it has been calculated that air temperature and relative humidity, as well as the source of ventilation air and the thickness of the population, can influence the overflow and transmission of a few pathogenic microbes.

Thermal comfort is also influenced by individual limits, such as the degree of activity, the clothing worn by the person, his or her age, health state, gender, and the change in temperature between the outside environment and the person's home [17]. Different factors such as overcrowding in rooms or under-inhabitancy may have an influence, as well as inconsistency throughout the day and over an extended period.

4.0 Conclusion

From previous research, it is possible to assume that this study's goals are to discover the link between bacteria and thermal comfort while also investigating the influence of bacteria on thermal comfort in a building, which is what this study is about. It is possible to conclude that the original study goal has been met based on its objectives. Bacteria are not one of the factors that impact the thermal comfort of a building. The thermal comfort of a building is determined by the individual, who prefers to be in a warm or cold environment depending on their preferences. The third objective is to identify the factors affects thermal comfort in building using bacteria. Personal factors and environmental factors are the two types of factors that influence thermal comfort, and they are classified as follows personal factors and environmental factors. In terms of human considerations, the metabolic rate and the level of clothing are important in terms of environmental elements, the parameters to consider are humidity, air velocity, air temperature, and radiant temperature. The bacteria must be in good temperature to ensure to be active.

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