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BIOBRICK PRODUCTION BY SOLID STATE FERMENTATION OF LATTERATE SOIL USING BIOPOLYMER GUM PRODUCING BACILLUS SUBTILIS

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Abstract:

There are many challenges faced by the modern brick industry, including cost, shortages of raw materials and environmental impacts of production. To meet this challenge, many research methods are followed around the world. This project is aimed at the production of bio bricks using laterite quarry waste powder, *Syzygium cumini* leaf extract and bacterium *Bacillus subtilis* through the process of Solid-state Fermentation. We had four different mixtures containing Soil and water, Soil and leaf extract, Soil-water and bacteria, Soil-leaf extract and bacteria. The brick made of leaf extract and bacteria is expected to have more compressive strength, water absorption, hardness and bacterial count. Our method of creating bio bricks from laterite quarry waste powder, solid state fermenting them with *Syzygium cumini* leaf extract and *Bacillus subtilis*, binding them, and compressing them into blocks offers significant fuel, energy, and material conversion cost savings. It also requires a lower capital investment per ton of cement and offers an ecologically sound solution. “Bio-bricks” made with this technique could be a brand, effective, and more environmentally friendly building material.

1. Introduction

As the globe experiences a peak in its careless environmental degradation and rapid resource depletion, it is important to decrease the usage of non-ecofriendly construction block materials available on markets. The present manufacturing process of building materials such as steel and brick emit large quantities of greenhouse gases like CO2 in to the atmosphere. Hence the, emerging

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economies have an important approach in this domain as they focus on, rapidly building their infrastructure while controlling the energy consumption and emission of harmful gases to the environment. This aims at producing an eco-friendly brick or a bio-brick which utilizes least energy consumption and causes no carbon emission and with less environmental implications.

Bricks made from plain soil for centuries have been used in building mud houses [1]. The most consistent of these soil types are laterites. In this mini project, we use laterite quarry waste powder as the key raw material for the construction of bio-brick. Laterite is an old and popular construction material that has served humanity for centuries now. It is a highly weathered tropical soil containing varying proportions of iron and aluminum oxides [2]. Along with mud homes and buildings, it is also employed in the construction of highways. When used alone, it depreciates in strength fast under load and ambient weather. A type of soil known as laterite is characterised as being found in hot, humid tropical areas of the world. It was created from weathered rocks under conditions of high temperature, heavy precipitation, and wet and dry intervals. [3]. The high rainfall leaches away the silica component and thereby making it rich in iron and aluminiumoxides. Iron oxide causes it to range in colour from red to brown to yellow. It hardens when exposed to air and is now a widely used building material in many parts of the world due to its accessibility and cost savings compared to other natural earth elements. Further to being more affordable than traditional modern building materials, it is also thought to have superior energy efficiency in tropical climates [4]. However, extraction of lateritic block results in large quantity of lateritic waste powder and disposing them is a major problem. To get around this significant problem, laterite quarry waste powder can be utilized to make bio bricks. Since laterite quarry waste powder has engineering properties as same as lateritic soil, can be utilized as an ideal alternative building material than other chemical and harmful materials [5].

This undertakes a biotechnological application known as solid state fermentation of laterite quarry waste powder to produce bio-brick. Solid state fermentation (SSF) is the fermentation process that takes place when there is no free water present or almost no free water present [6]. Despite being well-known since antiquity, SSF is currently receiving scientific interest because of the numerous environmental and apparent economic advantages it provides. For the generation of secondary metabolites, organic acids, fuel, and enzymes, among other things, solid state

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fermentation is frequently used [7]. It is a substitute for submerged fermentation because it requires less complicated cultivation equipment, less money upfront, higher productivity, less energy, less water, better product recovery, and less bacterial contamination. It also uses less energy and water overall. There are several factors, which affect the solid state processes and the nature of solid state is the most important factor. The substrate added should provide enough nutrients for the growth of microorganism present inside.

The advantage of a biotechnological method over a chemical one is that we can use affordable raw materials as a source of hydrocarbons, like *Syzygium cumini* leaf extract. It is also known as Java plum, Malabar plum, Black plum, Jambul. This will act as a natural nutrient medium and helps to the enormous growth of the bacteria *Bacillus subtilis*. The use of these substrates will also reduce environmental pollution caused by other artificial additives [7].

Brick mixture problems are caused by cracks. In order to maximise the structure's endurance, either the developed cracks are mended afterwards or additional reinforcement is added to the structure during the design phase to guarantee that the crack width stays within a predetermined range. Bacteria can be added to the brick mixture to help solve this issue by improving the durability of the brick [8]. Here is an attempt to make this possible by using Bacillus subtilis. In comparison to any typical brick mixture, this bacteria has demonstrated its ability to increase the compressive strength, tensile strength, and flexural strength. It develops in bare-bones medium without any additional growth agents. Most of them are mesophiles, which like temperatures between 30 and 35 °C [5]. It generates homo- and copolymers of polyhydroxyalkanoates (PHAs), broadening the variety of synthetic PHAs. Bacillus subtilis has the capacity to accumulate significant amounts of polyhydroxybutyrate (PHB).PHB accumulated is a highly crystalline thermoplastic polymer having a glass transition temperature of 0 to 5°C and a reasonably high melting point. PHB is completely biodegradable and insoluble in water. It is simple to cultivate and safe to employ *Bacillus subtilis* to enhance the brick mixture's strength properties [9].

This work illustrates the use of bacterial and biotechnological processes in the field of civil construction in a cost-effective and environmentally responsible way. This might be a low-input, sustainable alternative technology for the building and construction industry [10-15].

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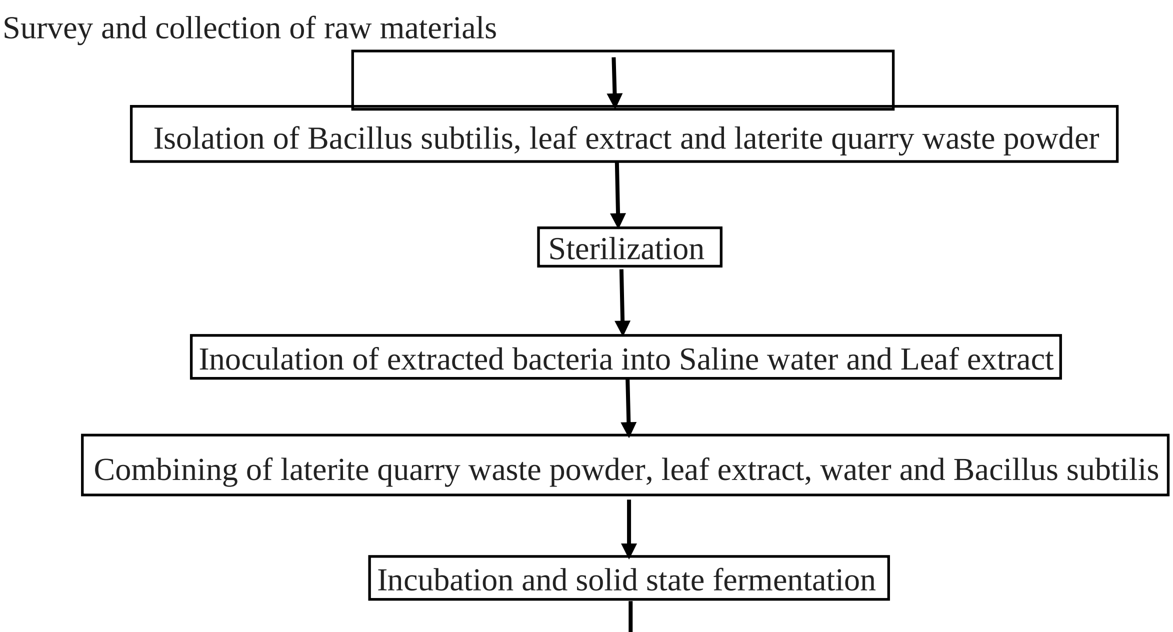
2. Experimental Procedure

The proposed methodology consists of casting and testing of bricks of size 190 × 90 × 90 mm which is obtained by mixing the constituent materials. The brick mould is made of four samples, firstly Soil and water: A known amount of sterilized laterite quarry waste powder is thoroughly mixed with distilled water to make a thick malleable paste. The second sample consists of soil and leaf extract: A known amount of sterilized laterite quarry waste powder is thoroughly mixed with the sterilized *Syzygium cumini* leaf extract to make a thick malleable paste. Third sample consists of soil, bacteria and leaf extract: A known amount of sterilized laterite quarry waste powder is thoroughly mixed with *Bacillus subtilis* inoculated through leaf extract to make a thick malleable paste. Lastly soil, bacteria and water: A known amount of sterilized laterite quarry waste powder is thoroughly mixed with Bacillus subtilis inoculated through distilled water to make a thick malleable paste [16].

Each of the four samples is filled in four different molds respectively by four layers. Each layer is compacted well to attain a maximum density and it reduces pores in the brick which results in increased durability and compressive strength of brick without heating process. The four molded brick samples are kept for Solid State Fermentation for 14 days. After the bacteria have had 14 days to proliferate, the brick samples are taken out of the mould and left to cure for a further 14 days in the open air. After total 28 days, the cured bricks are characterized using different test to identify the ideal bio brick.



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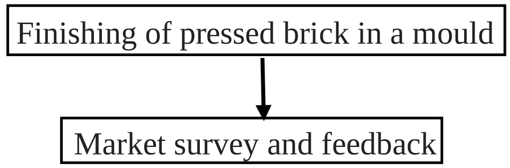

Fig 1. Methodology to produce Biobricks

To characterize the three samples of bricks, the following tests are conducted: Compressive strength test: The brick is placed in compression testing machine with the smooth surface at the top. Steel plate should be kept over the brick specimen to withstand the load and the load is applied gradually to the brick at the rate of 14 N/mm2. The load is applied until the brick fails. Water absorption test: The rate of water absorption is the important parameter of the brick because it affects mortar and grout bonding during the wall construction. Increased water absorption by the brick from the mortar causes a decrease in brick strength. In this test, a dry brick stored at room temperature is weighed initially before being fully submerged in water for 24 hours. The wet brick's weight is then calculated. The amount of water absorbed by the brick is calculated as the difference between the final average weight and the beginning average weight.

According to the Indian standard (IS: 1077: 1992) for the classification and specification of bricks, the quality of the brick is split into three groups based on its water absorption. First-class bricks shouldn't absorb more water than 20% of their own weight. Second quality brick should not absorb water more than 22 percentage and third quality brick should not absorb water more than 25 percentage [17].

Hardness test: here, a fingernail is used to make a scratch on a brick surface. Brick is considered to be sufficiently hard if no imprint is made on the surface. Bacterial count: From each of the four samples, a smear is made, and a spread plate culture is made under sterile circumstances. Then after the incubation for around 24 hours the colonies are counted using colony counter.

3. Results and Discussions

3.1 COMPRESSIVE STRENGTH TEST

The brick made of leaf extract and bacteria have more compressive strength which is 3.7MPa than the brick made without leaf extract and with bacteria. The brick made without leaf extract and

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bacteria is expected to have a low compressive strength when compared to other bio bricks [18-20].

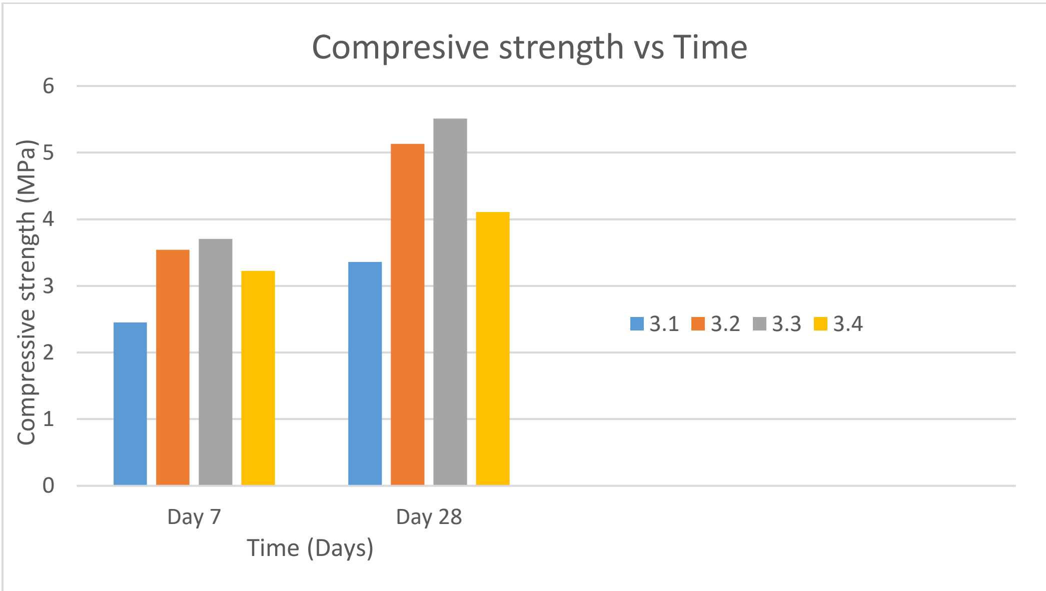

Fig 2. Comparison of samples in terms of compressive strength

3.2 WATER ABSORPTION TEST

The Indian Standard (IS: 1077: 1992) for bricks classification and specification is projected to be much more satisfied by bricks created using leaf extract and bacteria compared to bricks made without leaf extract and bacteria.

Table 1

Absorption Test Results of Bio-Bricks

Bio-Brick	W_1 (Kg)	W_2 (Kg)	Water Absorption (%)
1	2.76	3.16	14.4%
2	2.86	3.38	18.1%
3	2.64	3.14	18.93%
4	2.8	3.28	17.1%

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3.3 HARDNESS TEST

All the four samples of bio bricks have sufficient hardness which was found to be 1.2MPa.

3.4 BACTERIAL COUNT

The brick made of leaf extract and bacteria is expected to have more bacterial count which was around 10^8 than the brick made without leaf extract and with bacteria.

Fig 3.1 Soil and water brick

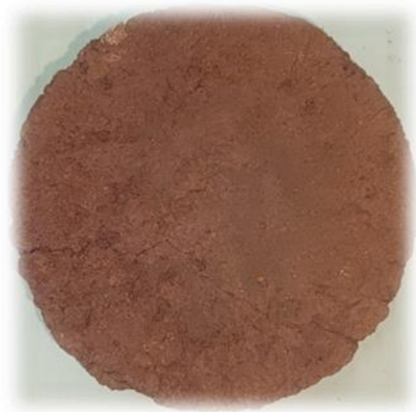

Fig 3.2 Soil and leaf extract brick

Fig 3.3 Soil, bacteria and leaf extract brick

Fig 3.4 Soil, bacteria and water brick

Fig 3. Bio-bricks produced

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4. Conclusion

Based on the literatures reviewed and the lab work carried out by our team, the following conclusions are made regarding the utilization of laterite quarry waste powder, leaf extract and bacteria for the production of bio-brick by solid state fermentation. Bio-bricks manufactured by the Solid-state Fermentation of laterite quarry waste powder using leaf extract and bacteria are 100% natural and sustainable. Solid State Fermentation enhances the ability of the bacteria to produce polymeric substances called PHB which provides automatic durability and self-repairing ability to the bio-bricks. The use of laterite quarry waste powder as an alternative to conventional building materials helps to reuse and overcome the problem with the disposal of laterite quarry waste. Laterite quarry waste powder helps to increase the compressive strength and hardness of the bio-brick. *Syzygium cuminias* an excellent natural nutrient media improves the durability and compressive strength of the bio brick.

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References

1. D Karunagaran, Eco friendly brick produced by the reaction of bacteria, International Journal of Chemical Engineering Research, vol 1, pp.1-5, 2014.

2. A. K. Kasthurba, M. Santhanam and M. S. Mathews, Investigation of laterite stones for building purpose from Malabar region, Kerala state, SW India – Part 1: Field studies and profile characterization, Construction and Building Materials, Vol.21(1), 2007, pp. 73-82.

3. NeelavSarma, Twahira Begum, Sudin Kumar Pandey, RoktimGogoi, SunitaMunda, Mohan Lal, Chemical Composition of Syzygiumcumini (L.) Skeels Leaf Essential Oil with Respect to its Uses from North East Region of India, Journal of Essential Oil Bearing Plants 23 (3), pp.601-607, 2020.

4. Jun Feng, Bingcheng Chen, Weiwei Sun, Yang Wang, Microbial induced calcium carbonate precipitation study using bacillus subtillus with application to self-healing concrete preparation and characterization, Construction and Building Material 280, 122460, 2021.

5. Jane-Yii, Hsiu-Feng Ye, Characterization and flocculating properties of an extra cellular biopolymer produced from a bacillus subtilis DYU1 isolate, Process biochemistry 42 (7), pp.1114-1123, 2007.

6. SwathiMohapatra, SudiptaMaity, HirakRanjanDsh, Surajith Das, Swathipattnaik, ChandiCharanRath, Devi Prasad Samantary, Bacillus and biopolymer: Prospects and challenges, Biochemistry and biophysics reports 12, pp.206-213, 2017.

7. VS ARANGARAJAN, M ARIVOLI, Eco friendly low-cost bio-brick, Volume:07 Issue:07/July 2020.

ISBN-978-81-19905-39-3

8. DigafeAlemu, WubetieDemiss, Gamachiskorsa, Bacterial performance in Crack Healing and its Role in creating Sustainable Construction, international journal of microbiology 2022, 2022.

9. K. Priyanka, S. Mohamed Uvais, A. Salman Khan, Alimurthaza, S. MahmadAshir, Experimental Study On Bio Brick Using Bacillus pasteurii, Vol 6, 2020.

10. MdFakruddin, MdAsaduzzamanShishir, Recycling and sustainable development, Recycle and sustainable development 16 (2023) pp.41-49.

11. Haruhiko Yokoi, Osamu Natsuda, Jun Hirose, Sachio Hayashi, Yoshiyuki Takasaki, Characteristics of a biopolymer flocculant produced by Bacillus sp. PY-90, Journal of Fermentation and Bioengineering 79 (4), pp.378-380, 1995.

12. Wan-TaekJu et al. BiotechnolLett. Enhanced production of poly-Gama-glutamic acid by a newly- isolated Bacillus subtilis, 2014 Nov;36(11):2319-24. Doi:10.1007/s10529-014-1613-3. Epub 2014 Jul 22.

13. Kuan Zhang, Chao-Sheng Tang, Ning-Jun Jiang, Xiao-Hua Pan, Bo LIU, Yi-Jie Wang, Bin Shi, Microbial-induced carbonate precipitation (MICP) technology: a review on the fundamentals and engineering applications, Environmental Earth Sciences 82 (9), 229, 2023.

14. Lung Shih, Pei-Jen Wu, Chwen-Jen Shieh, Microbial production of a poly (gama-glutamic acid) derivative by Bacillus subtilis, Process Biochemistry 40 (80), pp.2827-2832, 2005.

15. MattiaParati et al. Biotechnol Adv. Building a circular economy around poly(D/L-Gama-glutamic acid)- a smart microbial biopolymer, 2022 Dec;61:108049. Doi: 10.1016/j.biotechadv.2022.108049. Epub 2022 Oct 13.

16. Sing Chuong Chuo, SarajulFikri Mohamed, SitiHamidahMohdSetapar, AkilAhmad, Mohammad Jwaid, Waseem A Wani, Asim Ali Yaqoob, MohamadNasurMohamad

ISBN-978-81-19905-39-3

Ibrahim, Insights into the current trends in the utilization of bacteria for microbially induced calcium carbonate precipitation, Materials 13 (21), 4993, 2020.

17. Hong Xu, Min Jiang, Hui Li, Dingqiang Lu, Pingkai Ouyang, Efficient production of poly (Gama-glutamic acid) by newly isolated Bacillus subtilis NX-2, Volume 40, issue 2, Feb 2005, pp.519-523.

18. Ishwar Bajaj, Rekha Singhal, Poly (glutamic acid)-an emerging biopolymer of commercial interest, Bio source technology (10, pp.5551-5561,2011).

19. EnesEkinci, Ibrahim Turkmen, EmreBirhanli, Performance of self-healing geopolymer paste produced using Bacillus subtilis, volume 325, 28th march 2022, 126837.

20. Zhenxiang Lu, WeinaGuo, Chang Liu, Isolation, identification and characterization of novel Bacillus subtilis, journal of veterinary medical science 80 (3, 427-433, 2018).

ISBN-978-81-19905-39-3