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Strength Development in Bio Mineralised Steelslag Bricks using Micp Process

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Abstract*: Steel slag annual production in India is about 12 million tonnes per annum. Steel slag is one of the industrial residue came out from steel industries. The amount of steel slag produced from different steel industries is 150-200kg per tonnes of steel produced These steel slag is dumped in land and pollute the environment. Paper mills produce the large amount of lime sludge is about 5 lakh tonnes per annum. These steel slag used as binder material and coarse aggregate also in different sieve sizes. These both steel slag and lime material contains large amount of calcium mineral compared than other waste materials. The conventional burnt clay brick manufacturing firing process develops the 750 million tonnes of co_2 emissions per year. The Bio mineralised steel slag bricks developed by using these waste materials and bacillus bacteria. These microbes generates the calcium carbonate precipitation in the steel slag bricks. The strength development of these BMSS bricks were achieved by addition of NBU medium supply and carbonation process. The scanning electron microscope (SEM), mineralogical composition analysis, X-ray diffraction analysis, compressive strength and water absorption test are conducted to support the strength development in bio mineralised steel slag bricks.

Keywords*: bio-mineralisation, calcium carbonate precipitation, Carbonation, Strength, Micro-morphology.

I. INTRODUCTION

Microbiologically induced calcium carbonate precipitation (MICP) process develops the strength of bricks by using bacteria. [1] These Eco friendly bricks are reduce pollution compared than burnt clay bricks. These bacterial species are developed the strength of bio bricks at room temperature [2].The use of microbiologically induced calcium carbonates as binder material. Steel slag can be activated by artificial supply of co_2 [3]. Bacillus megaterium was able to produce large amount of urea and $cacl_2$.Calcium crystals precipitated by this bacteria. These Bio mineralised steel slag bricks can replaced for burnt clay bricks [4].Bacillus species are able to precipitate the calcium carbonate and develop the strength properties in these bacterial bricks [5].MICP process is the crack healing technique to repair the cracks. These microbiologically induced calcium carbonate precipitation produces the calcite minerals and fill the cracks in it [6].

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II. EXPERIMENTAL INVESTIGATION

A.Raw Material

B. Steel slag

The steel slag is grey in colour. The chemical composition of steel slag is given in Table.1.The calcium hydroxide content is high compare to others. The Bulk density of steel slag is 1020 kg/m^3 and fineness modulus is 2.8(3)

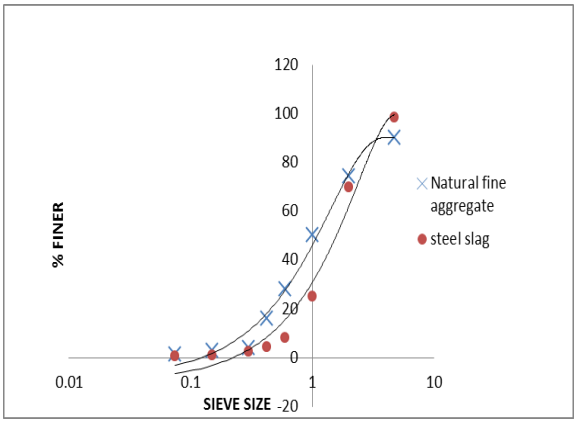


Figure 1 Particle size distribution of steel slag as per IS 383: 1970

C.Lime

Slaked lime is also called as hydrated lime. It is colourless crystal or white powder. The huge amount of 99.9% of calcium oxide presented in lime.

D. Bacteria

Bacteria from bacillus family is introduced in steel slag brick which are having calcium as their food from brick. The bacteria potency 2x10^8 CFU/ML.
The bacillus bacteria content 35-40% in 500 ml. Enzymes and vitamin 5% in 500 ml. Bacillus Megaterium is a rod shaped bacteria found in soil which is a non-pathogenic. The bacteria helps to develop the stiffness and strength in soil.

E. Nutrient broth medium

Nutrient broth medium is a general purpose medium used for cultivating a bacteria.
Nutrient broth medium contains beef extract as an aqueous extract of lean beef tissue extracts.
It contains Water – soluble substances of animal tissue, which include carbohydrates, Organic nitrogen compounds, water soluble vitamins and salts.

Table 1 Chemical composition %

Oxide composition	Steel slag	Lime
CaO	36.27	99.9
MgO	8.27	-----
SiO_2	16.6	-----
Al_2O_3	6.2	-----
MnO	1.88	-----
FeO	26.9	-----
P_2O_5	1.43	-----
Na_2O	0.16	-----
K_2O	0.03	-----
SO_3	0.5	-----

III. BIO MINERALISED STEEL SLAG BRICKS PREPARATION

A. BMSS bricks Preparation

Twelve Mix proportions by varying the SS/SL ratio 0.4 and 0.5 and addition of bacteria respectively. These bio mineralised steel slag bricks were developed by using MICP process addition with NBU and Carbonation process.

These Raw materials of steel slag and slaked lime were mixed with bacteria and water for 5 min first, and then were cast into moulds of 230mmx110mmx 75 mm [4].

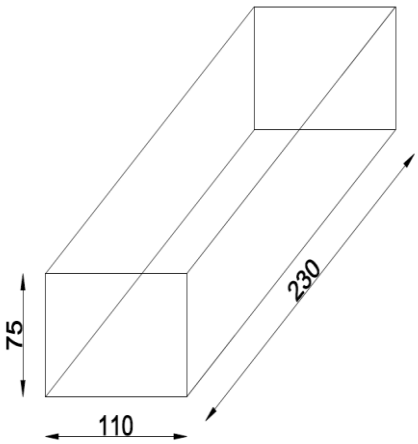


Figure 2 Size of Bio brick

All the samples were de moulded after 24 hour in dry curing at room temperature 36°c.Then these 6 brick samples were applied with nutrient broth urea medium regularly in sprinkling technique. These bricks were curing by NBU spray for 28 days.

Table 2

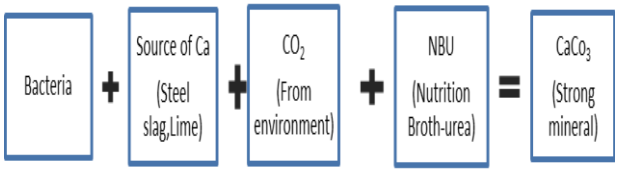
Brick name	bacteria	SS/SL ratio
BS_4	Bacillus Megaterium	0.4
BS_5	Bacillus Megaterium	0.5
Nb_4	Nil	0.4
Nb_5	Nil	0.5
BS_4 Ns	Bacillus Megaterium	0.4
BS_5 Ns	Bacillus Megaterium	0.5

The above Six bricks were tested before carbonation process. In this brick preparation process to rectify the requirements of sand and necessity of fuel also. The steel slag used as coarse aggregate and binder material also by varying sieve sizes. Lime mineral and bacteria used as binder material of this Bio Mineralised Steel Slag bricks. Bacteria is major content in these bricks to produce the calcium carbonate in it.

Figure 3 De moulding of BMSS Bricks

B. Microbiologically induced calcium carbonate precipitation

Microbes was performed to study the efficiency of bacillus megaterium to precipitate the calcite in Bio mineralised steel slag bricks. The bacteria potency $2x10^9$ CFU/ML. Bacillus megaterium cells are rod-shaped, Gram-positive bacteria that are naturally found in soil and vegetation. As pores gets compact and filled with calcium carbonate, the compressive strength of brick increases. This bacteria helps to develop the stiffness and strength improvement in steel slag bricks. Bacillus megaterium 50ml of this bacteria was mixed with 600ml of water in each steel slag bricks. After these bricks were De moulded and then applied Nutrient broth urea medium regularly. These NBU helps to increase the bacteria growth in Bio mineralised steel slag bricks. MICP result in a non-uniform distribution of the porosity and the permeability reductions. Microbial Induced Calcite Precipitation (MICP) is a biochemical process in which specific organisms produce extracellular calcium carbonate which is capable of crack healing.



C. Carbonation process

Carbonation process done by co_2 supply from this cylinders. Microbial induced calcite precipitation process done by these material. Calcium oxide is converted to the calcium carbonate ($caco_3$).Carbon uptake of 11% in 2 hour carbonation

Figure 4 Arrangement of Bio bricks for carbonation

Six bricks were arranged into the carbonation chamber and these bricks were made with different Mix proportions of SS/SL ratio and with NBU and without NBU conditions. These bio mineralised steel slag bricks were got better strength after carbonation process. The carbonation setup was shown in fig.6. In these carbonation process develops carbonate and calcite minerals in the Bio mineralised steel slag bricks.

Figure 5 carbonation process

It consists of a compressed co_2 Gas cylinder, Carbonation chamber, pressure transducer and a pressure regulator. Gas Pressure maintained 0.3MPa.The formation of calcium carbonate mineral present at following equation.

$CaO+co_2 \longrightarrow CaCO_3$.

IV. RESULTS AND DISCUSSION

A. compressive strength (Before carbonation)

These Bio mineralised steel slag bricks were tested in compressive strength testing machine to know about the crushing strength of bricks. The crushing strength varies between the different ratio and nutrient broth supply conditions. Six brick samples were tested one by one and average result taken as bricks compressive/crushing strength. The high compressive strength obtained bacillus subtilis bacteria with NBU medium supply. The compressive strength of Bio mineralised steel slag bricks were calculated before carbonation and after carbonation.

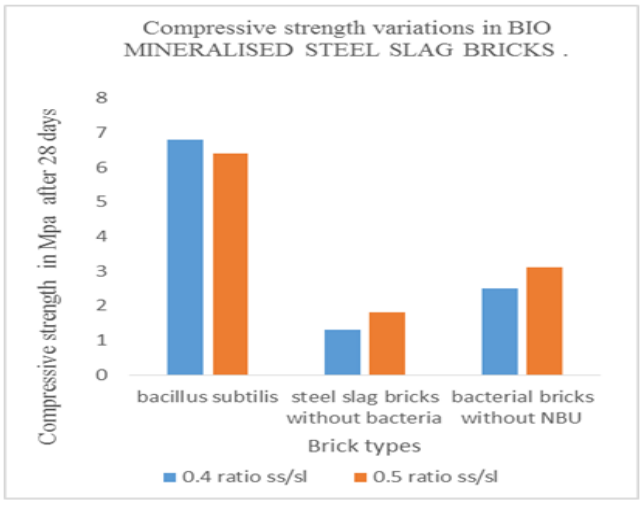


Figure 6 crushing strength of Bio mineralised steel slag brick before carbonation

B. compressive strength (After carbonation)

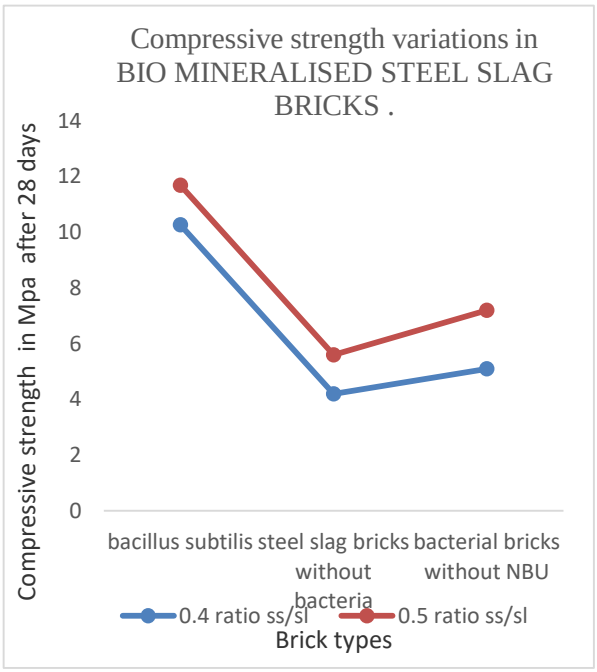


Figure 7 crushing strength of Bio mineralised steel slag brick after carbonation

C. Water absorption test

The BMSS bricks were weighed in dry condition and then immersed in fresh water 24 hours. Then the brick is weighed in wet condition. The difference between the weights is the water absorbed by brick. The good quality brick does not absorb water more than 20% of its own weight. The various water absorption values obtained in different ratio bricks.

The water absorption value is too high in without bacterial bricks compared than bacteria with NBU supply bricks. The water absorption test helps to identify the porosity and permeability capacity of BMSS bricks.

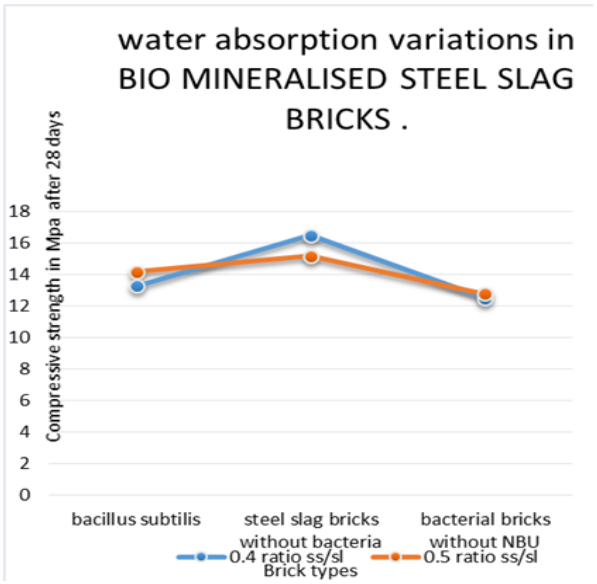


Figure 8 water absorption variations in Bio Mineralised Steel Slag Bricks

D. Efflorescence test

The test was conducted by the bricks were immersed in water for 24 hours. Then identify the deposition of patches. The deposit of efflorescence is nil in these BMSS bricks.

E. Micro structure analysis

The Scanning electron microscope (SEM) test of analysing inner micro structural brick surface and porosity. These analysis helps to identify the $CaCo_3$ deposits in BMSS bricks. This test was used to analyse the mineralised and un mineralised brick samples. The porosity was reduced due to presence of calcium carbonate content inner gap of pores.

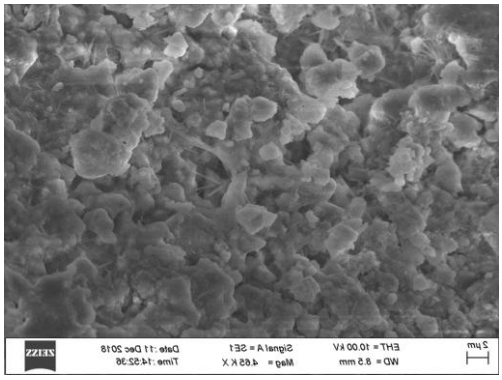


Figure 9 Un mineralised.

Rod shaped bacteria present in these un mineralised steel slag bricks. The microbial un mineralised and bacterial activity in inner surface of brick sample was easily analysed.

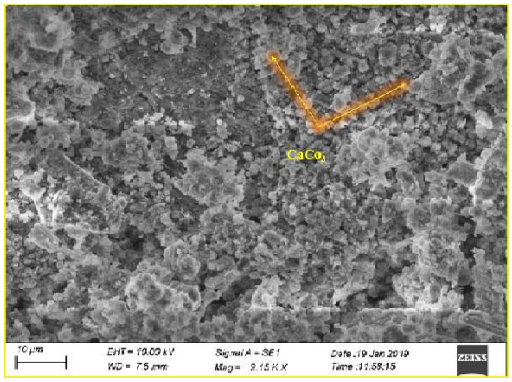


Figure 10 mineralised

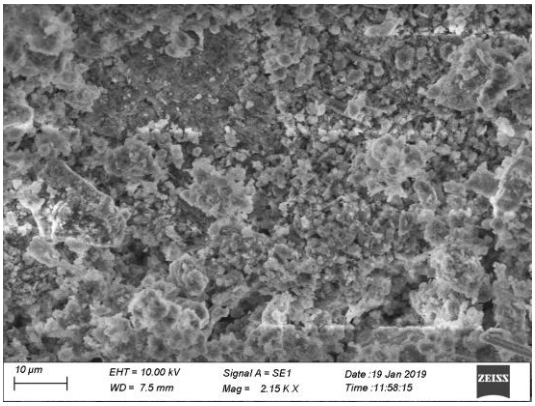


Figure 11 Microbial Mineralised after carbonation.

F. Mineralogical composition analysis

The EDX analysis is used to analyse the mineral composition in steel slag bricks. The microbial mineralised and Un mineralised bricks samples were tested. This analysis very helpful to identify the high amount of calcium carbonate content in brick sample.

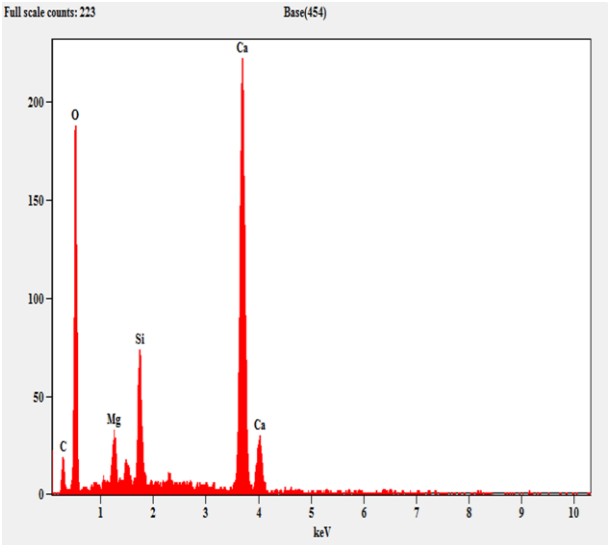


Figure 12 XRD patterns of mineralised

Table 6 XRD mineral composition

Element Line	*Weight %*	*Weight % Error*	*Atom %*
C K	9.82	± 0.87	15.51
O K	56.55	± 1.75	67.03
Mg K	2.39	± 0.18	1.87
Si K	4.03	± 0.29	2.72
Si L	---	---	---
Ca K	27.20	± 0.74	12.87
Ca L	---	---	---
Total	100.00		100.00

G. Chemical composition analysis

Chemical composition of Bio mineralised steel slag bricks sample were analysed in sona starch. These chemical composition variation between initial day to final day and analysed development of calcium carbonate content by bacterial activity and NBU supply.

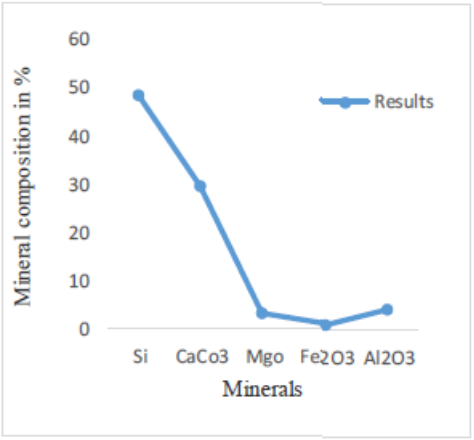


Figure 13 Mineral composition in initial day

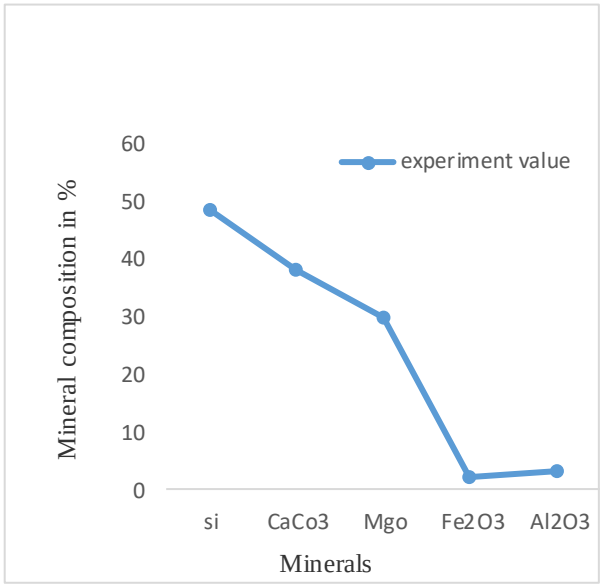


Figure14 Mineral composition in Final day

V. CONCLUSION

The Present study develops the strength of Bio mineralised steel slag bricks by using Bacillus subtilis bacteria.

The SS/SL Ratio 0.4 and 0.5 with regular 28days NBU curing develops calcium carbonate precipitation.

The compressive strength variation between SS/SL 0.4 and 0.5 ratios and before carbonation and after carbonation strength results are calculated.

High compressive strength 6.8MPa at before carbonation using bacillus subtilis with SS/SL 0.4 ratio.

High compressive strength 11.69 MPa at after carbonation using bacillus subtilis with SS/SL 0.5 ratio.

The 3h carbonation process develops the MICP process produces the calcium carbonate strong material and these material fill into pores to develop the porosity in BMSS bricks.

Water absorption test results were calculated in various Mix ratio of BMSS bricks. The chemical composition analysis helps to identify the calcium carbonate content growth in between initial day to final day by using bacterial NBU supply to these bricks.

SEM and XRD analysis indicate the development of strength by these microbial activity and presence of calcium carbonate formation and mineralisation process in these BMSS bricks.

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