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Research Article

THE POSSIBILITY OF CO_2 EMISSION REDUCTION BY USING BFS WASTE IN BRICK-MAKING PROCESS THROUGH CDM, IN INDIA: A SUSTAINABLE APPROACH

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ABSTRACT

The objective of this paper is to study the scope and possibilities of clean development mechanism (CDM) projects involving CO_2 emission reduction through blast furnace slag waste (BFSW) utilization in brick making process, initiated to replace the process of burnt clay brick. Today, the Steel plant industry generates a huge amount of blast furnace slag waste (BFSW), which in turn, has significant negative impacts on the surrounding environment, habitat, and ecology, it also has serious sustainability implications, especially if they are not properly managed. BFSW recycling as a sustainable construction material seems to be a viable solution not only to the environmental and ecological problems, but is also an economical option to transform waste into wealth in a sustainable way. In this study, we have experimented brick sample specimen by using blast furnace slag (BFS) and cement mix in various proportion and cured it in clean water for 28 days. The mechanical property was measured, where by a maximum compressive strength was found to be 24.41 MPa, which certainly is very promising, all the more so because it satisfies the IS Code 1077:1992 standard. The study suggests that compared to the process of traditional burnt clay bricks, the production of bricks by using BFSW consume minimal energy, while considerably reducing CO_2 emissions.We thereby explore the possibilities to achieve carbon credit (as defined in Article 12 of the Kyoto Protocol) through the CDM project, while developing a process technology for brick preparation using BFSW in order to provide a potentially sustainable solution. Apart from mitigating Greenhouse gas emissions, the development of process technology for utilization of solid waste such as BFS for processing brick making process in Clean Development Mechanism projects may provide substantial local economic, social and environmental sustainability benefits to host countries.

Highlights:

- A brief review of the present status of blast furnace slag waste (BFSW) and the recycling process is presented.
- Making bricks out of BFSW is explored.
- Mechanical properties are experimented up to 82% BFSW with 18% of cement
- Compressive strength, water absorption, bulk density are satisfactory
- Recycling BFSW for brick making process is recommended.

***Keywords**: Blast Furnace Slag (BFS), Waste, Burnt Clay Bricks, Environment, Kyoto Protocol, CDM, Sustainable solution*

INTRODUCTION

Adverse effects on the global environment isn't new, hazardous emissions causing global warming have thrown our lives out of gear, soaring temperatures across nations being one of the stark realities staring at all of us today (McMichael, 2000 ; Bilgen, 2014; Wilkinson *et al.*, 2007). In order to address issues related to global warming, the United Nations Framework Convention on Climate change (UNFCCC) was adopted in 1992, whereby the objective was to control and limit the GHG concentration in the atmosphere. Subsequently, the Kyoto Protocol to the UNFCCC came into force in February 2005. The protocol described and set the maximum GHG emission limit for countries. (Abate, 2005; Wara, 2007; Cifici, 2018; Kuriyama and Abe, 2018). Futher, this protocol has created a mechanism under which 192 parties have agreed to reduce greenhouse gas emissions globally. A venture or company belonging to a developed country has two different ways to reduce emissions one, it can do so by adopting new technologies or designs to improve upon its existing emission technology systems to attain the new norms. Otherwise, it could look to tie-up with developing nations and assist them to set up new environment-friendly technologies, which in turn would result in earning through carbon credits, and in the process, meet its emission reduction targets. Scientists must look to delve deeper with the resources available at their disposal, whereby they could develop a process technology, which would serve as a substitute for the burning of fossil fuel, thereby reducing the environmental impact (Böhringer and Vogt, 2003)

The United Nations Compensation Commission (UNCC) stated that "The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets (Couth and Trois, 2010; Bhargava *et al.*, 2017; Cruz *et al.*, 2017; Kanchinadham and Kalyanaraman, 2017).The mechanism is seen by many as a trailblazer. It is the first global, environmental investment and credit scheme of its kind, providing a standardized emission offset instrument, CERs."

Eligible Projects (CDM, UNEP, ISBN: 87-550-386-6, 2005)

The CDM will include projects in the following sectors:

- End-use energy efficiency improvements
- Supply-side energy efficiency improvement
- Renewable energy
- Fuel switching
- Agriculture (reduction of CH4 and N2O emissions)
- Industrial processes (CO_2 from Cement etc., HFCs, PFCs, SF6)
- Sinks projects (only afforestation and reforestation)

The Industrial processes sector does have a lot of scope to reduce GHG including CO_2 emission, by evolving a process for using wastes such as BFS (Menendez *et al.*, 2003; Unnikrishnan and Singh, 2010).

Due to rapid infrastructural growth, natural resources like the fertile topsoil, generally used for the process of burnt clay bricks are depleting fast (Provis *et al.*, 2010). It is no secret that traditional burnt clay brick, which we have been using since long, are now going to be banned by the Government immediately, as the process consumes a huge amount of fertile topsoil, which otherwise could be used for agriculture and habitation purposes. Important to note in here that the process of burnt clay brick consumes a lot of energy, as it needs to be heated up to 900^0C - 1200^0C by using coal and other fossil fuels, whereby it exponentially releases CO_2. In India,the Ministry of Forest and Environment (MoEF) along with the central pollution control board (CPCB) issued a notice to ban those very burnt clay brick processes immediately. Brick is one of the primary building materials throughout the globe. It is estimated that the growth rate of the construction sector in India has been at 6.6% per year from 2005, and is expected to remain steady there till about 2030 (Rajarathnam *et al.*, 2014). It has also been estimated that about 70 billion burnt clay bricks are produced in India annually, releasing thereby 28 billion kgs of CO_2 (Reddy & Jagadish, 2003). Interestingly, in 2013 alone, manufacturing of burnt clay bricks released a whooping 100.16 million ton of CO_2 (Maheshwari and Jain, 2017) thus, they are certainly unsustainable, and therefore finding a viable alternative is the need of the hour.

On the other hand, a huge amount of blast furnace slag (BFS) is being generated every year, degrading both the environment and ecology (Yi *et al.*, 2012; Francis, 2004). BFS waste consists of trace metal, a toxic element that flows in the form of leachates with rainwater, polluting the underground water and soil of the surrounding area (Das *et al.*, 2007). Dumping BFS occupies vast land area, which are then rendered unfit for agriculture, human and animal inhabitation. Stability of the BFS dump is of great concern, since it can easily slide and travel long distance causing irreparable losses for both humans and animals (Nicieza, 2007; Hua-dong *et al.*, 2009). As natural resources of construction materials are fast depleting, sustainable future for living creatures partially depends on the optimal utilization of industrial solid waste such as BFS etc. In India alone, around 11 million tones of BFS is generated every year (Pappu *et al.*, 2007).

BFS waste may be used as a raw material for cement production has been known for long (Kumar *et al.*, 2008; Tsakiridis *et al.*, 2008; Monshi and Asgarani, 1999). In fact, many cement manufacturers in India are using BFSW for producing cement (Nath and Kumar, 2016; Rai *et al.*, 2002). However, it has been seen that using BFS waste for cement production is both not suitable and feasible due to a weak cement clinker, additionally, the process in itself is highly cumbersome and energy intensive (Emery *et al.*, 1973; Shi, 2004; Li *et al.*, 2016), wherein each ton of clinker generates one tonne of CO_2 (Shi, 1999).

Using BFS waste for producing bricks to replace the fertile topsoil, could thereby be a sustainable solution, it is advantageous, as it would keep the environment safe by reducing GHG and eliminating dangerous toxic elements. Moreover, it would also reduce costs of preserving the BFSWdump, which can in turn save the land resources (Raut *et al.*, 2011). Using BFS through CDM project is feasible to earn carbon credit (Sreekanth *et al.*, 2014), as across the world, almost 15% waste-related CDM projects are approved (UNFCCC, 2003). One carbon credit is equal to the reduction of one ton of carbon dioxide from the atmosphere (Mondal and Sachdev, 2012; UNFCCC, 2003). In India, almost $28*10^6$ tone of CO_2 is generated every year from the process of burnt clay brick, which is equal to $28*10^6$ unit of CO_2 credit (Reddy & Jagadish, 2003), this, could be drastically reduced by replacing traditional burnt clay brick process with the process of brick making by BFSW. Through extant research, it is evident that both low carbon production processes and solid waste management are for public interests and governments worldwide.

MATERIALS AND METHODS

The BFSW used of this work is for making brick provided by the iron and steel company. In order to get uniform and fine grain particles, the slag was crushed and grounded in the laboratory, post which it was dried for further applications. Particle size analysis was performed on the materials using mechanical sieving. For preparing a brick sample, the particle size of the BFS that were used, were between 0.75 and 0.60 mm, the BFS sample were then washed with distilled water. Further, the BFS sample mix with ordinary Portland cement (OPC) with varying proportion, chemical composition of BFSW and OPC of three different samples were examined through a scanning electron microscope (SEM) shown in Table 2.1 Table 2.2 respectively.

Table 2.1. Chemical Composition of BFSW samples

Constituents	Sample A (%)	Sample B (%)	Sample C (%)
SiO_2	35.77	38.56	41.16
Fe_2O_3	0.87	0.53	1.23
Al_2O_3	14.98	11.82	9.82
CaO	37.16	36.68	34.68
MgO	7.1	8.79	9.79
SO_3	0.41	0.45	0.45
Na_2O	1.18	0.45	0.36
MnO	2.19	2.14	2.11

Table 2.2. Chemical Composition of Cement (OPC) samples

Constituents	Sample A (%)	Sample B (%)	Sample C (%)
Na_2O	0.46	0.16	1.09
MgO	1.73	1.91	1.69
Al_2O_3	4.99	3.89	5.89
SiO_2	22.11	18.66	20.66
P_2O_5	0.11	1.18	1.18
SO_3	4.11	5.77	3.88
K_2O	0.87	1.55	1.55
CaO	62.33	64.09	59.09
TiO_2	0.41	0.41	1.77
Mn_2O_3	0.83	0.13	0.13
Fe_2O_3	1.98	1.78	2.75

2.1 Mixing of materials

BFS grain and ordinary Portland cement (OPC) were mixed together with a specified quantity of water, mix proportion of the sample was presented in table 2.3

Table 2.3. Materials and mix proportion for preparation of Sample specimen

Sample ID	BFS Grain %	Cement (OPC) %
BFSC 1	97	03
BFSC 2	94	06
BFSC 3	91	09
BFSC 4	88	12
BFSC 5	85	15
BFSC 6	82	18

For sample preparation, we used cube molds of varying sizes(e.g. 70.6 mm x70.6 mm x70.6 mm) specified by IS Code of IS 10086-1982. The molds needed to be thinly coated with mold oil in order to prevent adhesion of materials specified by IS code 516-1959. The materials were hand-mixed with desired proportion as specified by IS Code 516-1959.

2.2 Casting of the sample

Three batches of sample specimen were cast in the cube mold of 70.6mm x70.6mm x70.6 mm for each type of brick sample. Immediately after mixing the composition, it was placed in the cube mold and compacted by hand tamping tools specified by IS code IS 516 - 1959.

2.3 Curing of the brick sample

Specimen were then removed from the mold after twenty-four hours, and placed in clean water in a water container for complete curing up to 28 days, this curing procedure has been prespcribed by IS 9013-1978.

2.4 Testing of Sample specimen

Mechanical and chemical properties were tested in the laboratory. Properties as compressive strength, bulk density and water absorption of bricks sample with BFSW and cement mix have been presented in Table no. 2.4.

Morphology of the cured sample was determined and presented in Figure 2.51 (a) (b).

2.4.1. Compressive strength testing

The compressive strength of the brick sample was determined using 3000 kN UTM machine. Compressive strength on 70.5mm cubes specimen was obtained after 28 days of the curing period. Test results of the three sample batchesare presented in Table 2.4., and the average has been presented in Table 2.5 respectively.

2.4.2. Water absorption test

One of the major factors affecting the strength and durability of brick is water absorption. Lesser the percolation of water in the brick, the more durable it is. So, the internal structure of the brick must be impervious to prevent water percolation. The water absorption was determined by using procedures described in (IS Code no- IS-3495, Part 2-1992) and result presented in Table no 2.4.

Table 2.4 Mechanical and physical properties of the brick sample

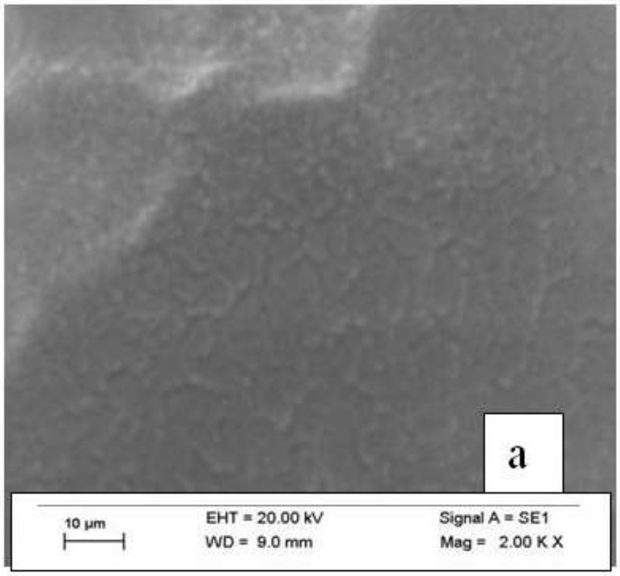
Sample Id	Compressive strength (MPa)			Water absorption (%)			Bulk density (gm/cc)		
BFSC 1	12.90	11.89	11.78	11.13	10.89	11.02	1.85	1.88	1.85
BFSC 2	13.67	12.71	13.54	10.75	10.02	10.54	1.89	1.88	1.89
BFSC 3	14.98	16.02	15.10	10.06	9.87	10.02	1.92	1.90	1.89
BFSC 4	19.01	18.11	18.98	9.19	9.11	9.16	1.96	1.88	1.91
BFSC 5	23.18	22.08	22.54	9.10	9.03	9.04	2.06	2.09	2.01
BFSC 6	23.67	25.01	24.54	9.03	8.97	8.78	2.11	2.16	2.13

Table 2.5 Average mechanical and physical properties of the tested brick sample

Sample Id	Compressive strength (MPa) Average	Water absorption (%) Average	Bulk density (gm/cc) Average
BFSC 1	12.19	11.01	1.86
BFSC 2	13.31	10.44	1.89
BFSC 3	15.37	9.98	1.90
BFSC 4	18.70	9.15	1.92
BFSC 5	22.60	9.06	2.05
BFSC 6	24.41	8.93	2.13

2.33 SEM (EDAX) analysis

The composition of BFSW and Cement (OPC) used in the process as determined in SEM(EDX),has been presented in Table no.2.1, and 2.2 respectively, the morphology of the brick sample has been presented in Figure 2.41a, and Table 2.41b. In the morphology image, it was seen that the particles were closely interconnected, form thereby a monolithic bond, due to which, the durability of the brick seemed to be good. Additionally, owing to the curing process, the water particles were cemented together by hydration reaction to achieve a solid durable structure.



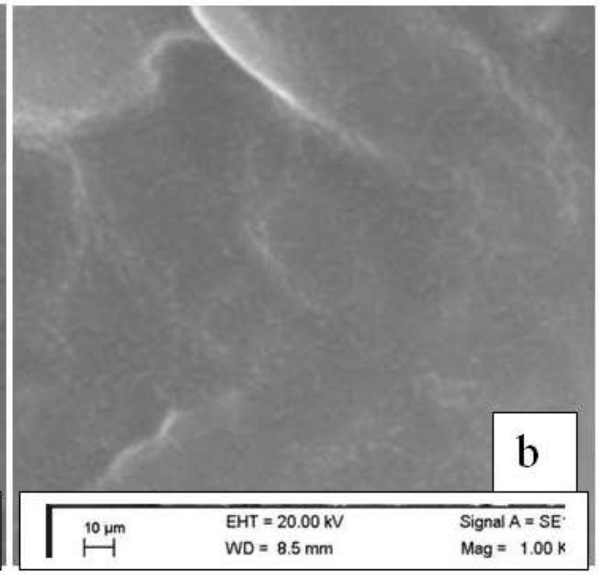


Figure 2.41 (a)(b): SEM (EDX) analysis of BFS waste brick made in accordance with the mix of OPC cement

RESULTS AND DISCUSSION

The data obtained fromthe test indicate that using BFS waste with cement (binder) can produce good quality brick, the result is very similar to the traditional burnt clay brick. Our result satisfied the IS Code 1077-1992, where the strength range of burnt clay brick is 3.5 MPa- 40 MPa.Moreover, we achieved an average compressive strength 12.19 MPa-24.41 MPa presented in table 2.5, conform to the IS Code 1077-1992. Physical properties such as water absorption and bulk density were also in consonance with the IS code 2180-1988. It has been observed that the increase of cement quantity compressive strength increases, while compressive strength in itself has a tendency to decrease with increases of BFS quantity, as presented in Fig 3.1.

Since we have the cold methods, we assure that it is pure carbon positive, thereby, the process can reduce a huge amount of GHG in the atmosphere.

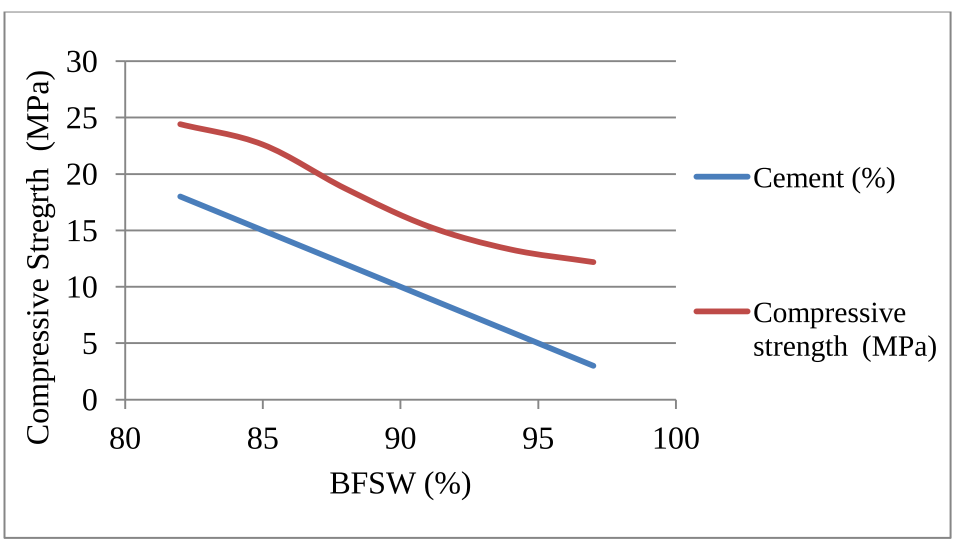


Figure 3.1: Compressive strength varying with the quantity of Cement and BFS

The measurements of the bulk density of samples with different proportions of BFSW and cement are shown in Fig.3.2.The results indicate that decreasing the BFS, results in an increase in the bulk density.

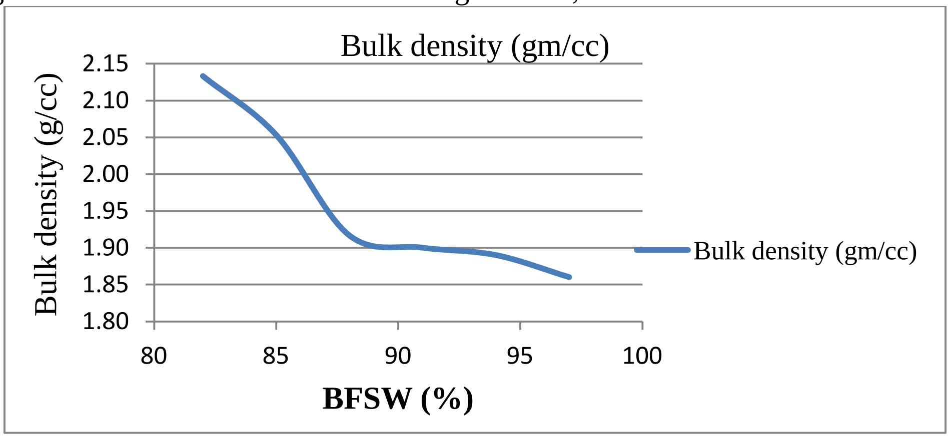


Figure 3.2: Bulk density increases with decreasing BFSW quantity

The water absorption rate refers to the quantity of moisture in the pores. Fig. 3.3 shows that increasing the BFSW quantity, water absorption rate also increases and on increasing of cement quantity water absorption rate also decreases.

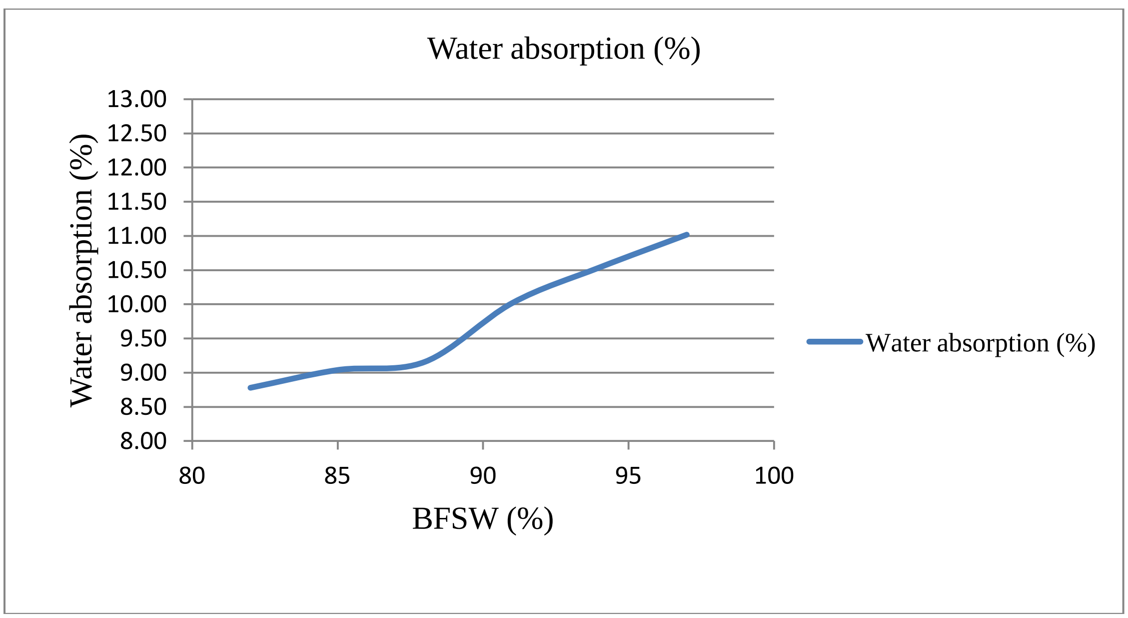


Figure 3.3. Water absorption increases with the increasing of BFSW quantity

Conclusion

It may be concluded that CDM projects in using BFSW for making bricks could possible help India and the world at large in multiple ways, the most important benefit being the reduction of GHG emission, while maintaing sustainability on natural resources of construction materials. To achieve CDM approaches successfully, it is very important to design and operate optimum process technology for efficient use of BFSW for making brick for the construction sector. In our study, we achieved a compressive strength of the brick, similar to that of a burnt clay brick, which is quite a good result in itself. So, good quality bricks can be produced by using BFSW with cement as a binder. In India, lot of BFSW is generated annually, as mentioned earlier, it can replace fertile topsoil using for making traditional burnt clay brick. Thus, the process is almost pure carbon positive except energy consumed for cement manufacturing process, used specifically for this process. There is a possibility to register this process as a CDM project, which can earn a credit of CO_2. Additionally, with this proposal, there would be a scope to earn revenue, which in turn could lead to economic and sustainable development in the country. Through this process, we could also get rid of the harmful effects on the environment, saving our valuable ecology there of. Thus, BFSW bricks can be manufactured beneficially in the vicinity of BFS waste dump areas. Our study shows that in India, there are ample opportunities to develop a more scientific process to using BFSW for making bricks in civil engineering applications, where by we could gain carbon credits as per CDM guidelines.

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