Use of Solid Waste Pyrolysis Char to Produce Masonry Bricks

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***Abstract*— Studies have been conducted for the utilization of biochar in the construction and building industries and it has been identified as a promising approach to decrease carbon dioxide emissions and contribute towards achieving carbon neutrality.**

The purpose of this study is to explore the possibilities of utilization of Char produced from pyrolysis of Solid Waste instead of biochar as a building material, in order to reduce problem of huge Solid Waste landfills and mitigate its environmental impacts.

An experimental study has been conducted to observe the feasibility of utilization of Solid Waste Char in higher proportions for production of Masonry bricks.

***Index Terms*—Utilization of Solid Waste Pyrolysis Char, production of Masonry Bricks.**

I. INTRODUCTION

Disposing of municipal solid waste (MSW) is one of the most significant environmental problems that contemporary society faces. Municipal solid waste (MSW) landfilling is typically the easiest solution to the disposal problem, but it has a hidden cost. The end result is environmental contamination, the loss of valuable raw materials that can be recycled, and the removal of a sizable portion of land from practical uses

Among the negative consequences of landfills are: Air pollution, ground water and soil contamination, disruption of biodiversity and habitat loss, greenhouse gas emissions, and health issues in nearby dwellers.

Currently used waste reduction methods include composting, incineration, recycling, and waste-to-energy conversion; of these, waste-to-energy and incineration are the most commonly used. While only 30% of Municipal Solid Waste is reduced using Incineration and Waste-to-Energy techniques, , the remaining Waste, including the leftover matte from the aforementioned processes remains in landfills.

While incineration raising pollution concerns, *Pyrolysis offers a potential solution*. This thermal process breaks down solid waste in the absence of oxygen (or limited oxygen), creating new products from the original material

The Process involves shredding of Solid waste and feeding it into a pyrolysis reactor. High temperatures (450-650°C) causes the waste to break-down into three main products:

Syngas: is a mixture of flammable gases that can be utilised to produce energy.

Bio-oil: A liquid substance that may be utilised as fuel.

Char: A solid residue that may be further processed or landfilled with reduced volume.

Advantages:

- *Waste Diversion:* Pyrolysis reduces the amount of waste going to landfills.
- *Energy Recovery*: Syngas and bio-oil can be used as fuel sources.
- *Reduced Emissions*: Compared to incineration, pyrolysis produces fewer harmful air pollutants.

Limitations:

- Cost: Setting up and operating pyrolysis plants can be expensive.
- Byproducts: Syngas and bio-oil may require further treatment before use.

Although Pyrolysis offers a promising alternative for waste management nevertheless it leaves behind char which is again a waste material that still goes into landfills.

The leftover solid residue (Char), is not just a waste; it still holds some hidden potentials. Rich in carbon, char can have various properties depending on the original waste. It can be porous, with a high surface area, making it useful for:

• Adsorption: Char can trap pollutants like heavy metals from water or air.

• Soil Amendment: Char can improve soil fertility and water retention in agriculture.

• Fuel Source: Under certain conditions, char can be a low-emission fuel source.

One particularly interesting application of pyrolysis is its potential for carbon sequestration, the material rich in stable carbon, when applied to soil, biochar can lock away this carbon for centuries, preventing its release as CO2.

Pyrolysis for carbon sequestration offers a glimpse of a circular solution – waste becomes a tool to fight climate change, while improving soil health.

While challenges remain, this technology has the potential to be a valuable weapon in the fight for a sustainable future.

II. LITERATURE REVIEW

Various published research reports, journal articles, and other documents have been reviewed, only a selection of the most significant ones are being included here.

1 -Nithyalakshmi, B. & Soundarya, N & Praveen, S. (2022). Characterization of Biochar Bricks to be used as a Construction Material. Journal of Physics: Conference Series. 2332. 012015. 10.1088/1742-6596/2332/1/012015.

Summary:

a) Biochar Bricks: The study explores biochar bricks as a sustainable construction material, with potential to reduce global warming.

b) Composition and Tests: Two types of biochar bricks were tested, one with 70% biochar and 30% cement, and another with 45% biochar, 45% plastic, and 10% cement1.

c) Performance: The bricks underwent various tests for compressive strength, water absorption, hardness, flammability, and insulation value23.

d) Potential: Biochar bricks show promise as a construction material, particularly the type with 70% biochar, which may be a viable alternative to traditional concrete bricks with further research.

2 -Dezhen Chen, Lijie Yin, Huan Wang, Pinjing He. Pyrolysis technologies for municipal solid waste: A review. Waste Management,Volume 34, Issue 12, 2014, Pages 2466-2486, ISSN 0956-053X, https://doi.org/10.1016/j.wasman.2014.08.004. (https://www.sciencedirect.com/science/article/pii/S0956053X14003596)

Summary:

• Pyrolysis Review: The document reviews pyrolysis technologies for municipal solid waste (MSW), focusing on technologies, reactors, products, and environmental impacts.

• Operating Parameters: It discusses how temperature, heating rate, and residence time affect pyrolysis behaviors and products1.

• Technology Evaluation: Various pyrolysis technologies and reactors are evaluated, including fixed-bed, rotary kiln, and fluidised-bed reactors2.

• Environmental Considerations: The review also addresses emissions from pyrolysis processes and contaminants in products, suggesting measures to improve environmental impacts

3 -Suarez-Riera, Daniel & Restuccia, Luciana & Ferro, Giuseppe. (2020). The use of Biochar to reduce the carbon footprint of cement-based materials. Procedia Structural Integrity. 26. 199-210. 10.1016/j.prostr.2020.06.023

Summary:

a) Biochar in Cement-Based Materials: The study investigates the use of Biochar microparticles as a green filler in cement paste and mortar composites to reduce the carbon footprint of cement production1.

b) Environmental Benefits: Biochar, a byproduct of biomass energy recovery processes like pyrolysis, can improve the mechanical properties of cement while maintaining environmental benefits.

c) Optimized Biochar Use: An optimized percentage of 2% Biochar by weight of cement was found to increase strength and toughness without compromising ductility2.

d) Sustainable Solutions: The research contributes to the growing interest in sustainable solutions for reducing the environmental impact of cement production

4 -Vikas Kumar, Anil Kumar Chhotu, K. Mani, Deepak Gupta. Use of Waste Materials in Construction Work: Step Towards waste

Minimization 2021 IOP Conf. Ser.: Mater. Sci. Eng. 1145 012164

Summary:

a) Waste Material Reuse: The document discusses innovative ways to recycle waste materials from human and industrial activities, which traditionally have no lasting value, for use in construction work.

b) Sustainable Construction: It emphasizes the importance of sustainable construction practices due to the construction industry's significant consumption of natural resources and production of waste.

c) Recycling Benefits: Highlights the environmental and economic benefits of recycling, such as saving energy, reducing pollution, and minimizing landfill waste.

d) Materials for Soil Stabilization: Examines the use of various waste materials like glass, scrap tires, and fly ash for soil stabilization in construction, improving soil properties and contributing to more sustainable infrastructure.

III. RESEARCH GAP

Although studies have been conducted for the utilization of biochar (char obtained from pyrolysis of organic materials like wood chips, leaves and agricultural waste) in the construction and building industries and it has been identified as a promising approach to decrease carbon dioxide emissions and contribute towards achieving carbon neutrality, however the potential of using Solid Waste char in the construction industry has not received much attention.

IV. OBJECTIVE

This work attempts to investigate the possibility of using char derived from pyrolysis of solid wastes, as a raw material in construction Industry by producing Masonry bricks with Solid Waste Char, to enable its disposal at a large scale.

V. MATERIALS & EQUIPMENTS

Materials used in the experiment:

1- Solid Waste:

Segregation of Solid Waste components from a Municipal Solid Waste sample, and drying it out, would have been a difficult process, therefore food waste component was collected from home and sundried, while other components were sourced from scrap dealers

2- Cement / Aggregate / Water

Table 1. Materials for Brick Moulding

Ingredients	Source/Type
Cement	Nuvoco Double Bull 43grade OPC
Aggregate	3 mm
Char	Obtained from Pyrolysis of Solid Waste Components
Water	Tape water

Equipments used:

- Mild-Steel molds measuring of 200 x 90 x 150 mm
- 60 Ton Hydraulic Cold Press Machine - FCP-50T
- Digital Compression Testing Machine - Aimil
- Hand Mixing Tools: Shovel, Trowel

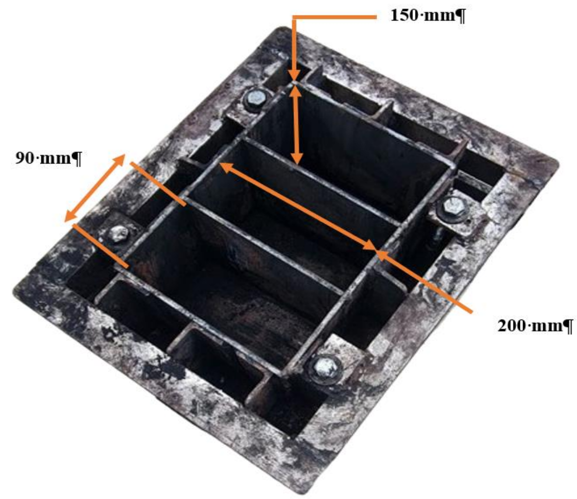

Figure 1 Mild Steel Mould used for Brick Production

VI. METHODOLOGY

For the experiment the following mixes of mortars were selected for producing masonry bricks:

a) Cement, small aggregate (3 mm), Solid Waste Char, with cement, small aggregates, and Char in the ratio of 1:3:3, here the percentage of char will be 43%

b) Cement-Char mortar with the ratio 1:1.67 i,e. Char percentage is 62.5%

c) Cement-Char mortar with the ratio 1:4 i,e. Char percentage is 80%

The objective of the study was to explore and demonstrate the potential of using Char of Solid Waste as a raw material in construction industry by producing Solid Waste Char Bricks, our work started with procurement of Solid Waste Char.

A brief survey of different Municipal waste disposal facilities revealed that DELHI/NCR does not have any pyrolysis units for processing municipal solid waste. As a result, in order to obtain the requisite char for the experiment, solid waste samples had to be collected and pyrolysis had to be done in an onsite developed Pyrolysis Reactor Prototype.

Sampling of Solid Waste:

Since the municipal solid waste is a complex mixture of various materials organic and inorganic, to start with, it was necessary to standardize the Solid Waste Samples to obtain consistent results.

Taking this into consideration, six essential components of solid waste—food waste, paper, cardboard, plastics, garden trimmings, and wood, were identified and included in our study with the following dry mass percentages:

Table 2. Components of Solid Waste with their Dry Mass Percentages, taken for the experiment

Solid Waste Component	Percentages by Dry Mass
Food Waste	6.1
Paper	57.1
Cardboard	12.8
Plastics	13.2
Garden Trimmings	5.4
Wood	5.4

The solid waste component composition shown above, along with their corresponding percentages, is based on the composition adopted by Howard S. Peavy in in his book Environmental Engineering in most of the practical illustrative problems of Solid Waste Management.

The said Six key components were taken in weight proportion as per Table 2, and were trimmed and shredded into small pieces for preparation pyrolysis feedstock

Pyrolysis of Solid Waste Components

The Pyrolysis Reactor Prototype developed for pyrolysis of solid waste components consisted of a) steel tank of volume around 20 litres, with a sufficiently large hole at the top to fill the feedstock and a cap that can be tightly fastened using a nut-bolts system, and an exit pipe for discharge of flue gases. b) a high-volume commercial LPG burner stove to act as heating source.

The pyrolysis reactor had sufficient thermal insulation of glass wool to reduce heat loss and maintain the required temp throughout the process.

A few tests were conducted prior to pyrolyzing the solid waste components to ensure that the pyrolysis process would continue at a temperature of between 500 and 600 degrees Celsius.

The pyrolysis of Solid Waste Components carried out for at least 1 hour, for each batch.

After pyrolysis, the char produced, was ground into a fine powder.

Solid Waste Char as aggregate replacement material in production of Masonry Bricks

In order to test the feasibility of utilizing large quantities of Solid Waste Char, the following concrete/mortar mixes were made:

Table 3. Design Mix for Char Bricks

Mix Ratios (by Wt)		
Mix 1	Char	3
	3 mm stone aggregate	3
	Cement	1
Mix 2	Char	1.67
	Cement	1
Mix 3	Char	4
	Cement	1

For the preparation of the mortar, a W/C ratio of 0.5 was used, and the char was moistened priorly around 30% by weight.

For brick molding, Mild-Steel molds were prepared measuring of 200 x 90 x 150 mm.

A total of 9 Bricks were moulded, 3 for each mix, by filling the molds with mortar mixes, and were pressurizing using hydraulic compression machine with a load of 20 Tons on each mold for compaction.

Curing

The bricks were left to dry for 24 hours and cured with intermittent water sprinklers for 7 days

Testing of Char Bricks

After curing for 7 days, the bricks, were tested for compressive strength using Aimil CTM and following observations were obtained:

VII. RESULT

Applying the pressure by the hydraulic press machine, compacted the mortar filled in the steel molds and as a result the height of the bricks produces was reduced to less than. half of the mold height

Table 4. Brick Dimensions after compaction

Mix Name	Brick Size
Mix 1	200 x 90 x 67 mm
Mix 2	200 x 90 x 56 mm
Mix 3	200 x 90 x 52 mm

Table 5. Average weight of Solid Waste Char Bricks

Mix Name	Average Weight
Mix 1	1.56 kg
Mix 2	1.43 kg
Mix 3	1.11 kg

Figure 2 Moulded Bricks After 7 day curing

Table 6. Compressive Strength of Char Bricks @ 7 days curing

Mix Name	Ave Comp Strength
Mix 1	7.17 MPa
Mix 2	7.63 MPa
Mix 3	5.19 MPa

VIII. DISCUSSION

Bricks were tested for compressive strength after just 7 days of curing due to time constraints and the limited scope of the experiment. Assuming 65% strength development on day 7, the 28-day compressive strength can be estimated as follows:

Table 6. Estimated Compressive Strength of Char Bricks @ 28 days curing

Mix Name	Ave Comp Strength
Mix 1	~ 11 MPa
Mix 2	~ 12 MPa
Mix 3	~8 MPa

The above estimates are still conservative, while Biochar is known to facilitate long term hydration reaction of cement, the compressive strength of the tested bricks is anticipated to be higher than these values.

nevertheless, given their projected strength, solid waste Char bricks can be utilized for non-structural strength applications such masonry blocks, filler Concrete, pavements, and recreational and decorative uses Solid Waste Char Bricks are 55% to 35% lighter in weight than a Fired Clay Brick, making it suitable for masonry work

IX. METHODOLOGICAL LIMITATIONS

1-Due to time constraint, only a 7-day curing compressive strength strength has been examined, when a 28-day curing strength would have been more meaningful.

2-Only the compressive strength of Char bricks has been examined due to limited scope of the study, for practical applications, it would be necessary to investigate additional characteristics such as Flexural Strength, Insulation Value, Water Absorption, Flammability, and other long-term Durability issues.

3-Due to limited scope of the project, the Pyrolysis reactor developed during the project for char production, was very basic and less-refined, a more refined and suitable Pyrolysis reactor is recommended, since the process conditions and parameters, such as pyrolysis temperature, rate, and pressure, affect the structure of the char production [19].

4-Detailed study of physical properties chemical properties and elemental analysis of the Char, would have been preferable to understand its interaction with cement.

5-The feedstock used for study had only few key components while the actual Municipal Solid Waste consists of numerous components

6-While usage and disposal patterns are constantly changing, the feedstock components and their corresponding proportions, taken from Peavy et al. [11], are based on research conducted between 1978 and 1982

X. CONCLUSION

1-The practice of landfilling with Municipal Solid Waste, certainly does not address the problem of Solid Waste disposal in an environment friendly and sustainable manner

2-Lower environmental impact construction materials are the need of hour, and in order to reduce the carbon footprint of construction Industry.

3-Certainly, there exists a scope for disposal of higher quantities of Solid Waste Char, in production of non-structural elements like Masonry Blocks, Sidewalks, Borders, Filler Concrete and recreational & decorative applications

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