A Comprehensive Characterization of Cow Dung as a Construction Material

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Abstract- This paper characterises the locally available waste material i.e. cow-dung for affordable and sustainable development in construction sector. By introducing "cow-dung," as a new construction material, focus is on bringing this material into a new and sustainable domain. It is concluded that cow dung can be used as a main/bulk material or supplement material in brick masonry and in plastering the walls. The paper summarizes that the use of cow-dung and cow dung ash in brickwork significantly enhance the structural integrity and strength of structure. The improved strength, binding property, thermal insulation, water resistance property and carbon neutrality of cow dung create the opportunity to use it as a transformative element in sustainable construction. However, due to low mass density the use of cow dung is limited to patrician walls and not recommended for load bearing walls.

Keywords– Cow dung, Brick, building material, construction material, insulation

1. INTRODUCTION

The importance of utilisation of waste material is increasing with voice of sustainable development on global platform (Buraimoh et al., 2020). The use of locally available waste material not only reduces the cost of applications but also resolves the problem of disposal and saves the cost of disposing it (Ilbas et al., 2022, Cai et al., 2018). As the population continues to expand, so does the need for construction and housing. Presently in Rajasthan (India), various types of bricks are used in construction, such as first-class earth bricks, second-class bricks, sundried bricks, fly ash bricks, AAC blocks, and so on. Cow dung-based bricks are environment friendly as they store the carbon permanently in the structure resulting in lower greenhouse gas emissions (Costa, 2018).

This paper focused on introducing "cow-dung" as a new material in brick making and other construction applications, aiming to integrate it into a sustainable domain. Continual global climate change impacts all aspects of our life. The 2018 Paris Agreement strives for enhanced planning, implementation, and evaluation of long-term climate actions worldwide. Despite Australia's small population share (0.33%), it ranks amongest the top 10 per capita greenhouse gas emitters, emphasizing the urgency for comprehensive mitigation strategies (Tran et al., 2023). Philips (2020) found that most of the students were not familiar with sustainable construction. yet they emphasized the importance of gaining knowledge in this field. While technological transformation is evident in some sectors, the construction industry has long grappled with this challenge, with few firms achieving innovation (Pavan, 2021). In recent years, the marketing of sustainable construction materials has surged in popularity globally, driven by their environmental, social, and economic benefits (Caleb, 2020).

Many researchers are exploring cow-dung as a crucial resource in the pursuit of renewable construction practices. Historical importance of cow-dung has spurred the dedicated efforts of using it as a raw material in various applications. Cow-dung is now being harnessed to create superior alternatives such as bricks, plaster, and paint. This has elevated cow-dung to a more effective and eco-friendly choice compared to conventional materials. Research indicates that incorporating 5 to 10% cow-dung ash in brick production significantly boosts their tensile strength. This exemplifies the potential of cow-dung as a transformative element in sustainable construction.

2 COW-DUNG AS A CONSTRUCTION MATERIAL

Cow-dung, historically venerated in India, is traditionally considered sacrosanct and is sourced from healthy cattle. Cow-dung and cow urine are recognized by its ritualistic and purifying properties. From a scientific standpoint, cow-dung is rich in diverse minerals, rendering cow-dung to a valuable resource for various renewable applications. Cow-dung utilization spans across multiple domains, with ongoing scholarly investigation into its potential.

In India's historical architectural practices, cow-dung, in conjunction with soil, is employed for the construction of residences and courtyards. Vedic architectural principles endorse the use of cow-dung in plaster and bricks due to their exceptional resilience. The annual production of cow-dung amounts to a substantial 1212 million tons, further underscoring its significance as a resource (Monu Dalal, 2021).

Mix for brick manufacturing-

MIX_{brick} = Cow-dung (78% -80%) + Lime 20% + Cow Urine (1-2 %) (1)

For Vedic Plaster

$MIX_{plaster}$ = Cow-dung 30% +Gypsum 60 %+Gawar gum (5%) +Mud (3%) +Water (2%) Citric acid (1%) (2)

Cow-dung, when employed as a building material in the form of cob, represents an ancient architectural method. Cob is crafted by amalgamating indigenous clay, cow-dung, and straw. Cob maintains a stable thermal profile, exhibiting insulating properties that preserve warmth during colder seasons and promote cooling in warmer climates. This inherent feature significantly augments the energy efficiency of structures. Furthermore, cow-dung can be utilized in a manner akin to adobe, a distinct building material. In this process, cow-dung is moulded into brick shapes and subjected to sun-drying, facilitating its structural application (Anaadi Fondationn, 2020).

By incorporating soil and fiber into cow-dung during brick production, there's a reduction in CO2 emissions by up to 90% and a simultaneous enhancement of the bricks' structural integrity by around 20%.This approach is currently being implemented in a project based in Uganda (Material District, 2023). In the Sungani region of Ghana, an evaluation was conducted on earth bricks stabilized by cow-dung to assess their strength and durability. Results revealed that after a 10-minute immersion in water, there was a significant difference in the compressive strength of the bricks. Incorporating 20% cow dung content into the brick significantly decreased water absorptivity, reducing it from 16.8% to 10.4% in comparison to bricks without cow dung. Moreover, increasing it to 20% further enhanced abrasion resistance (Manu, 2013). In Netherlands, research initiatives such as NWO (New World Order) and NWA (Nationale Wetenschaps agenda) have endorsed the proposition of utilizing bricks composed of mud and cow-dung.

This approach engenders a sustainable circular impact, exemplifying principles of a circular economy and resource efficiency (Kulshreshtha, 2020). The unique combination of Cow-dung: 0.4 kg/kg, Lime: 0.4 to 0.6 kg/kg, Gypsum: 0.05 to 0.1kg/kg, Guar gum (as necessary), Lemon juice/citric acid (as required), Water (as needed) forms the foundational constituents for small scale buildings. It demonstrates considerable promise for sustainable building applications (Swadeshivip, 2022). By considering sustainability of construction materials incorporating cow-dung and cow waste, results in guide towards a positive ecological direction. These materials exhibit properties of being lightweight and breathable, contributing to a favourable ecological impact (Makunza & Kumaran, 2022).

When incorporating 10%, 20%, or 30% cow-dung into construction materials, followed by sun-drying and subsequent incineration to obtain ash, it is observed that integrating 10%, 20%, or 30% of this ash directly substitutes for 10% of the strength of the bricks. (P.Magudeaswaran, 2018). During the microstructural examination, the impact of cow-dung was closely examined, uncovering the presence of truncated, undigested fibres composed of cellulose, hemicellulose, and lignin. When cow-dung undergoes a reaction with kaolinite and fine quartz in the soil matrix, it generates insoluble silicates. These silicates affix to discrete particles, ultimately facilitating the cohesive formation of adobe bricks (Millogo et al., 2016).

Fig 1: Cow-dung brick

Cow-dung ash is utilized alongside cow-dung, offering a highly sustainable alternative to cement. The compressive strength testing period for cow-dung ash spans 7, 28, and 56 days, consistently yielding values exceeding 3N/mm² for each replacement according to IS 4031-6 standards. Notably, at 56 days, cow-dung ash exhibited a strength of approximately 10 N/mm², representing around a 10% increment. The optimal strength, approximately 25%, was attained at the best replacement percentage (Kamat et al., 2021). Use of cow-dung into the bonding-mixture for masonry work of partition walls showcases notable performance and exhibits considerable potential as an adaptive material for apartment units. The composition, consisting of 70% cow-dung and 30% organic building material, represents a straightforward yet effective solution (Julita et al., 2022)

Cement, as the second most utilized building material globally, significantly contributes to carbon emissions, thereby exacerbating global warming through its greenhouse gas effect. Furthermore, the energy expenses incurred in cement production surpass the total production costs. In this context, cow-dung ash emerges as a promising substitute. Its utilization doesn't contribute to greenhouse gas emissions, positioning it as an eco-friendly replacement for cement. Notably, in rural areas of India where cattle rearing is predominant, annual cow-dung production ranges from approximately 21 tons per year (depends on cow weight), presenting a substantial and readily available raw material source. Thus, incorporating cow-dung ash as an alternative to cement could present a sustainable and environmentally conscious option.

The production of 1 ton of cow-dung ash necessitates only 3.5 tons of raw cow-dung material. Cow-dung is obtainable in two forms for market use: fresh or wet cow-dung and aged cow-dung. Incorporating cow-dung ash in construction processes enhances structural strength by approximately 15% to 20%, diminishes permeability, lowers the pH level, and exhibits waterproofing properties. These characteristics make cow-dung ash a compelling and versatile material for diverse construction applications (Ramachandran D, 2018).

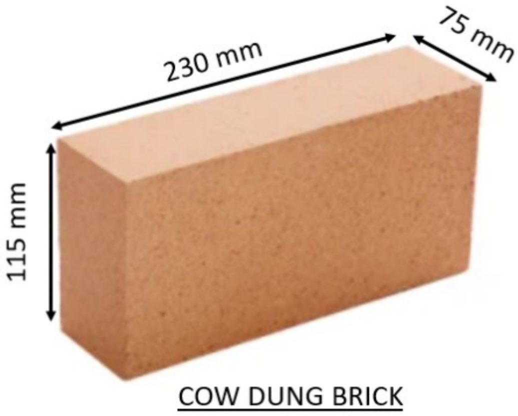

Fig 2: Dimension of bricks

A standardized production machine is used to manufacture the bricks using cow-dung and clay soil. This process involves compression of the mixture to attain the desired brick shape, typical size of approximately 230mm (length) × 110mm (breadth) × 85mm (height). These bricks undergo monitoring and assessment at various intervals, such as 15 days, 30 days, 45 days, 60 days, and 90 days, to evaluate their properties and durability over time.

Clay soil, one of the most popular building material, has been utilized since approximately 4300 BC. Its combination with cow-dung in brick production signifies a convergence of ancient materials with contemporary manufacturing techniques, demonstrating an amalgamation of traditional practices within modern construction methodologies (Katale, 2012).

It was noted that the stabilize, in the form of approximately 10-15 percent cow-dung in the cement mixture contributed to a big extent in slowing down the rate of deterioration, and the strength of the bricks was enhanced. In addition, water absorption and erosion tests indicated that such bricks had low water absorption. The increase in weight was insignificant, even when the samples were immersed in water and 24 hours had passed (about 0.001 grams). Interestingly, the water erosion potential of the bricks was also increased by this composition (Ullah et al., 2021). In the rural communities, cow-dung is also used to make a mixture with straw dust, which is used to form a waterproof layer used on walls and buildings. This combination can be an efficient insulator in houses and it protects against cold and heat. Further, this combination is also used to manufacture fibreboards, so that they can be used as alternative building materials in a number of ways such as in the production of furniture. This scientific practice emphasizes the wide range of application of cow-dung and straw dust, both as an environmentally-friendly product and as a sustainable alternative in construction and the manufacture of materials (Owlcation.com, 2021).

The Dungse Labs, based in Gandhinagar, is conducting an on-going research to convert cow-dung into sustainable high-quality materials at Hyderabad. It is a venture between an Indian and a Dutch startup. The project entails the utilization of cutting-edge technologies and procedures in order to use cow-dung to make eco-friendly building products, fertilisers, and other sustainable products. Such endeavours promote environmentally conscious innovations and signify a stride towards sustainable development (Sonika Pulluru, 2023).

2.1 Primeval scenario:

Cow-dung, a natural waste product, has been utilized for approximately 5000 years as a sustainable building material. When mixed with mud, it forms a durable compound used for constructing floors and as plaster for walls in houses. This composite offers thermal insulation, especially beneficial in colder regions. Moreover, in Indian traditions, cow-dung has been mentioned as a component for creating one of the five natural homes in the Rigveda. Beyond construction, cow-dung finds multifaceted applications globally, serving as fuel, fertilizer, a coating for floors and walls, a mosquito repellent in Central Africa, and an insulator in colder areas. This illustrates its diverse practical applications beyond its traditional use in construction.

2.2 Present scenario:

Cow-dung, available globally, is particularly abundant in regions like India where cattle rearing is prevalent. On a daily basis, a single cow typically produces about 10 to 20 kilograms of dung. Worldwide, 170-204 crore kilograms of cow-dung are produced per day. A report by Food and Agriculture Organization (2017) also indicated that 66.74 billion kilograms of manure were produced by dairy cows, non-dairy cows, and buffaloes. It is already estimated that 2600 million tons of livestock dung could be used.

Fig 3: Vedic bhavan made by cow dung (Monu Dalal, 2021)

This immense amount is employed in illustrating the ease with which cow-dung is available to be used as a resource of immense usefulness at the global scale. The article by Monu Dalal, (2021) talks about the construction of a Vedic Bhawan in Rohtak, India. The other thing that astonished me was that this was the only building to be built incorporating cow-dung as a construction material.

- Location – Near Sheela Bye Pass, Rohtak, Haryana
- Built by – Dr. Shiv Darshan Malik
- Built Year – 2018
- Total area – 700 sqm. (0.167 acre)
- Built up area – 400 sqm. (0.1 acre)

In his research work, Kulshreshtha (2020) examined the indoor climate of houses that were built in the Netherlands whereby the houses were built with a mixture of mud and cow-dung. These mud and cow dung structures are a testimony to the use of these resources in the ancient construction style of the land.

3 PROPERTIES OF COW-DUNG

3.1 Thermal properties:

- **Combustibility** Cow-dung is highly combustible and it is a common form of fuel in most regions of the world. It is also naturally high hence burnable.
- **Calorific value:** Cow dung has a calorific value of 13700 -16780 (Iftikhar et al., 2019), and is generally of moderate heating value when burnt. It has less energy in a unit mass of coal or wood.
- **Insulation:** The cowdung, when compact on a dry basis, can also be used as a thermal insulator. Some cultures have traditionally used it in the construction of walls or floors since it is an insulator.
- **Variable composition:** The thermal properties may change with changing dung composition i.e. moisture content, fibrous material and other organic matter.

Table 1: Result of thermal conductivity and resistivity of cow-dung

Percentage (%)	Thermal conductivity	Thermal Resistivity (r) m^2K/W
20	202.22	0.3807
40	132.11	0.5526
60	128.46	0.5994
80	220.60	0.3490

The investigation on the thermal characteristics of cattle manure had remarkable insights on the behaviour of the manure related to temperature and moisture content. Both of these factors have an effect on specific heat, thermal conductivity and thermal diffusivity. The results show that the effect of moisture content is more significant on specific heat and thermal conductivity, but the effect of temperature is more significant on the change in thermal diffusivity.

The regression models developed were found to be correct estimates of these properties, which proved useful to the engineers who design thermal equipment in consideration of dairy cattle manure to make more efficient and effective systems design (Nayyeri et al., 2009). When the cow-dung powder is added to polyester composite as an ingredient, a significant reduction in thermal conductivity can be noticed. Using a mixture of unsaturated polyester resin at different proportions of 3 per cent, 6 per cent and 9 per cent cow-dung, a hybrid composite is developed, known as cow-dung/glass fibre hybrid composite.

The effects on thermal resistivity which are observed are the main ones affecting the heat capacity of this composite. Interestingly, the thermal conductivity of the cow-dung-based glass polyester hybrid composite is lower than that of the corresponding composite based on solely glass Fibers reinforcement (Ranjeth Kumar Reddy et al., 2014). This fact implies that the addition of cow-dung as the additive alters the thermal properties of the composite, thereby decreasing its thermal conductivity. This change can be due to some intrinsic characteristics of cow-dung influence on the mechanism of heat transfer in the composite.

Table 2: Physical and chemical properties of cow dung

Dairy Cow Slurry Physical and Chemical Properties			
Proximate analysis (weight percentage)		Ultimate analysis (dry and ash free)	
Total solid content (%)	10.0	Carbon (%)	58.62
Volatile solid content (%)	8.0	Hydrogen (%)	7.69
		Nitrogen (%)	2.92
		Sulphur (%)	0.27
		Oxygen (%)	30.50

These outcomes indicate the possible use of cow-dung as a functional additive, which affects the thermo behaviour of composites with the inclusion of glass fibres and polyester resin. Increase in Total Solids concentration (TS) of cow dung causes a reduction in specific heat and an irregular distribution of thermal conductivity. At low TS, thermal conductivity is directly proportional to the slurry density and changes to bulk density independent at TS of greater than 51%. These changes are noted in this study as they are important to maximizing the heat-related processes of dung in agriculture and waste management (Chen, 1983).

3.2 Chemical properties

- **Organic Composition:** Cow-dung contains organic complex compounds (cellulose, hemicellulose, lignin and proteins).
- **Nutrient Profile:** Cow-dung is an organic fertilizer which adds essential plant nutrients to the soil such as nitrogen, phosphorus and potassium (NPK) which enhance soil fertility and plant growth.
- **Microbial Diversity:** Cow-dung supports a strong microbial community such as bacteria, fungi and other microorganisms that actively contribute to the breakdown of the organic matter and conversion of

other nutrients, which is essential to its fertilization properties.

- **pH Balance:** Fresh cow-dung usually has a slightly alkaline to almost neutral PH range of about 7-8.5 and this can change with conditions such as diet and aging of dung.
  Trace Elements: Trace elements present in cow-dung include calcium, magnesium, sulphur and other micronutrients which affect the chemical composition of cow-dung.

3.3 Physical properties

- **Moisture and Total Solids Concentration:** The dung has a moisture content of 71 to 78 percent and overall solids content of 19 to 24 per cent, which means that there is a lot of water in it and that it has decided on the solid materials in the dung.
- **Bulk Density:** The bulk density of the dung, which is between 1009 and 1030 kg/m3 and has varying total solids concentrations (20% to 27%), also changes the mass per unit volume of the dung.
- **Friction Coefficients:** The coefficient of friction when dry dung is 0.81 to 0.69, whereas the coefficient of friction varies with the water moisture content and these coefficients depict the tendency to resist movement on various surfaces.
- **Dynamic Viscosity:** The changes in viscosity of fresh cattle dung in relationship to dung to water proportions (1:1, 1:0.75, 1:0.50, 1:0.25 and 1:0) illustrate that the resistance to flow is significantly different when the dung is diluted with water.

Table 3: Physicochemical properties of undigested cow-dung

Parameters	Cow-dung
Moisture (%)	15.70
Ash (%)	20.10
Fibre (%)	19.50
Fat (%)	11.00
Crude Nitrogen (%)	1.40
Crude Protein (%)	8.75
Total Solids (%)	77.38
Volatile Solids (%)	27.01
Energy Content (%)	3.76
Carbon Content (K/g)	32.92
Carbon: nitrogen ratio (C/N ratio)	23.51

The results offer an in-depth description of the physical properties of cow dung, which is important in various applications of this material including agricultural use, waste disposal plans, and material science projects.Understanding these properties aids in optimizing utilization strategies and designing processes involving cow dung (Akash Lima, 2022).Cow-dung ash (CDA) in concrete offers benefits like lightweight properties and low thermal conductivity but has drawbacks: notably low strength (5-10% of normal concrete), unsuitability for high-stress areas or moisture-rich environments. It's best for specific uses with limited structural demands (Dhiraj Thakur, Suraj Thakur, Neeraj Pal, Pranav Kasbe, 2019).

4. SUMMARY

Author	Material	Application	Conclusion
Monu Dalal, (2021)	Cow-dung, mud	Cow-dung brick, Vedic plaster, Mortar, Tiles, Slabs, Fibreboard	Suitable building material, environmentally friendly and application across various domains
Anaadi Fondationn, (2020)	Soil, clay, cow-dung and straw	Coating on wall, floor etc.	Cow-dung functioning as an efficient soil stabilizer, presence of fibres within cow-dung aids in the prevention of cracking
Material District, (2023)	Earth, cow-dung, and agricultural waste	Buildings, house, farms etc	Bricks are eco-friendly, contribute 90% reduction in CO_2 emissions, 20% stronger and 50% cheaper
Manu, (2013)	Earth, cow-dung and ash	-	Incorporating 20% cow dung content into the brick significantly decreased water absorptivity, reducing it from 16.8% to 10.4% in comparison to bricks without cow dung. The abrasive resistance increased with increase in the cow-dung content up to 20%.
Kulshreshtha,(2020)	Mud, cow-dung	Construction material	Excellent water resistance property, capable of absorbing and releasing moisture.
Swadeshivip, (2022)	Cow-dung, lime, gypsum, Gwar gum.	Foundation and other	Bricks are compact, serves as good foundation mixture
Makunza & Kumaran, (2022)	sisal fibres reinforced concrete	Construction material	Exhibit lightweight and breathable, contributing to a favourable ecological impact.
P.Magudeaswaran, (2018)	Pozzolans, concrete, ashes from combustion of agricultural solid waste	-	Brick of clay and cow dung exhibits slightly lower strength. The void spaces in the brick increased due to the adoption of hand mixing and compaction of bricks.
Millogo et al., (2016)	cow-dung, cement, lime and bitumen	-	Addition of cow-dung improves physical properties, mechanical properties and water resistance of adobe bricks.

Author	Material	Application	Conclusion
Kamat et al., (2021)	Cow-dung ash, cement, sand	-	The 15% cow-dung ash improves strength in 56 days, 25% cost effective but reduced workability. Reduce setting time and favourable to hot weather conditions.
Julita et al., (2022)	Cow-dung, straw, lime, water, cement	Construction building material	Useful in partition wall, boasting a lightweight, solid composition. Comprehensive suitability needs to investigate.
Ramachandran D, (2018)	Cow-dung ash, concrete	-	Cow-dung ash enhance concrete durability and reducing cement usage, showcasing improved concrete properties and antibacterial effects.
Katale, (2012)	Clay soil, cow-dung, sustainable bricks	-	20% cow-dung addition led to the improved compressive strength; different durations showed varied optimal cow-dung proportions for maximum strength.
Ullah et al., (2021)	Soil, Cow-dung, cement, and lime	-	Cow-dung and cement enhance compressive strength, cow-dung and straw improve flexural strength and erosion resistance, offering cost effective potential for affordable housing.
Owlcation.com, (2021)	Cow-dung, cow pat etc.	-	Cow dung serves as a source of fuel, acting as an insect repellent when used in wall coatings.

5. CONCLUSIONS

Through this broad effort of research, articles, reports and studies, it becomes clear that there are numerous advantages to cow-dung based building material Definitely:

- Examples of eco friendly alternatives include cow-dung and cow-dung ash bricks which has a lower environmental footprint.
- The hygroscopic properties of cow-dung when used as a building material are shown to help in humidity control, to give a stabilizing effect on the change in temperature (Insulation of walls).
- The use of cow-dung as a construction material does not produce any carbon emissions and thus the environmental outcome would be a zero carbon emission profile.
- The cow-dung Composite Material has good strength and has great development prospects in construction. Thermal conductivity of composites is decreased with the use of cow dung in the presence of glass fibre and polyester resin.
- Cow-dung addition increases the compressive strength and structural integrity of bricks and provides a less expensive and environmentally friendly building material.
- Building materials derived from cow-dung exhibit low mass density thus, can be used in patrician walls easily.

Additionally, the future outlook for cow-dung as a construction material is highly promising, as ongoing research endeavours continue to explore and expand its applications within the field.

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