International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
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DEVELOPMENT OF SUSTAINABLE BRICK USING COW DUNG

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ABSTRACT

Fired clay bricks are the most widely used walling material in India, but their manufacture consumes fertile topsoil and large amounts of fuel and releases greenhouse gases and particulate matter. Cow dung is an abundant agricultural by-product that has been used in vernacular earth construction for centuries, and recent laboratory studies show that it can improve the water resistance of earth blocks. This paper reviews published work on the use of cow dung in bricks and earth blocks, summarises the mechanisms proposed to explain its effect, and compares the reported compressive strength, water absorption and durability results. On the basis of this review, a mix design with cow dung contents of 0, 5, 10, 15 and 20% by mass of the dry mix (soil plus dung), and a testing programme following IS 3495 and IS 1077, is proposed for developing a low-cost sustainable brick. The reviewed studies indicate that cow dung improves cohesion, crack resistance and resistance to water in unfired earth blocks, whereas in fired bricks higher dung contents increase porosity and water absorption and reduce strength. The optimum dung content therefore depends on the soil and the production method and must be established experimentally for the local soil.

Keywords: Cow dung, Sustainable brick, Earth block, Compressive strength, Water absorption, Agricultural waste, Low-cost housing, Durability

I. INTRODUCTION

Brick is one of the oldest and most widely used building materials. Conventional burnt clay bricks require fertile topsoil as raw material, and their firing in kilns consumes coal, firewood or agricultural residue and emits carbon dioxide and fine particulates. As the demand for housing and infrastructure grows, there is increasing interest in bricks that use waste materials, need less energy to produce and remain affordable for low-income households.

Cow dung is available in large quantities in rural India, where cattle rearing is widespread. It has traditionally been used as fuel, manure and a plastering material for floors and walls, and it is now studied as a bioresource for several other applications [1]. In earthen construction, dung is mixed with soil to reduce cracking and to make blocks and plasters more resistant to water.

Millogo et al. [2] reported that the main effect of adding cow dung to adobe blocks was a marked improvement in water resistance, which makes such blocks suitable for wet climates.

The results reported in the literature, however, come from different soils, dung contents, moulding methods and curing or firing conditions, so it is difficult to judge which findings apply to a given local soil. This paper therefore (i) reviews the published evidence on cow dung as an additive in bricks and earth blocks, (ii) compares the reported performance with the requirements of IS 1077 for common burnt clay building bricks, and (iii) proposes a mix design and test programme for developing a sustainable brick using cow dung. The aim is a brick that makes use of an agricultural waste, reduces the use of fuel and cement, and is suitable for low-cost construction.

Problem Statement

Brick kilns draw heavily on topsoil, and the removal of this soil reduces the land available for farming. Firing adds to fuel consumption and air pollution around kiln clusters. At the same time, rural areas generate large quantities of cattle dung that is often used only as fuel or left to decompose. Bringing these two issues together, a brick that replaces part of the soil with dung and avoids or reduces firing could lower both the demand on soil and the energy needed per brick. Whether such a brick can meet the strength and durability expected of a walling unit is the question this work addresses.

Objectives

1. To review the available literature on the use of cow dung in bricks, adobe and compressed earth blocks.
2. To propose a mix design with cow dung contents of 0 to 20% by mass of the dry mix for a local clayey soil.
3. To define a test programme based on IS 3495 for compressive strength, water absorption and efflorescence, with wet strength as an additional check for unfired bricks.
4. To outline how the results will be compared with IS 1077 and how the optimum dung content will be selected.

Scope

This paper is a review and a proposal for experimental work. It does not report new test results. The values quoted from other studies are taken from the sources cited and are not re-measured here. The findings apply to the soils and conditions of those studies, and the proposed programme is meant to establish the corresponding behaviour for the local soil.

II. METHODOLOGY

A. Materials. Soil: a locally available clayey soil, free of organic matter and coarse gravel, passed through a 4.75 mm IS sieve. Its grain-size distribution and Atterberg limits are to be determined before mixing, because the response of a soil to dung depends strongly on the soil type [3]. Cow dung: fresh dung collected from local cattle sheds, sun-dried for several days, broken up and sieved. Pachamama et al. [4] found that whole or ground dry dung gave no significant difference in earth mortars and that a 72 h fermentation period before moulding improved durability under water; a short fermentation step is therefore included as an option. Water: clean potable water.

B. Preliminary tests on materials. Before the bricks are made, the soil and the dung are characterised so that results can be interpreted and repeated.

- **Soil:** sieve analysis and hydrometer test for grain-size distribution (sand, silt and clay fractions), liquid limit, plastic limit and plasticity index, specific gravity, and the shrinkage limit. A soil with very high clay content is expected to shrink and crack on drying, while a very sandy soil may lack cohesion, so the fractions guide how much dung and water the soil can take.
- **Cow dung:** moisture content after sun-drying, bulk density, and pH. The pH is worth recording because the reported range of 6.5–9.5 is central to the discussion of the stabilisation mechanism in Section II-A. The fibre content and particle size after sieving are noted, and the animal diet is recorded because it is reported to influence the behaviour of dung in earth materials [4].

C. Mix proportions. Five mixes are proposed, with cow dung at 0 (control), 5, 10, 15 and 20% and dry soil at 100, 95, 90, 85 and 80% respectively, so that soil and dung together always make up 100% of the dry mix by mass (Table 1). This range spans the dung contents used in earlier studies of earth blocks and bricks [5], [6]. Water is added separately, and its content for each mix is adjusted to give the same workable, plastic consistency so that the mixes can be compared. The water added to each mix is recorded as a percentage of the dry mass, because dung is fibrous and absorbs water, so the water demand is expected to change with dung content.

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Table 1: Proposed mix proportions (percentage by mass of the dry mix; water added separately)

Mix ID	Dry soil (%)	Cow dung (%)	Total dry mix (%)	Water (added)	Purpose
CD0	100	0	100	Adjusted for same consistency	Control
CD5	95	5	100	Adjusted for same consistency	Low dung content
CD10	90	10	100	Adjusted for same consistency	Medium dung content
CD15	85	15	100	Adjusted for same consistency	Medium–high dung content
CD20	80	20	100	Adjusted for same consistency	High dung content

D. Brick preparation. The dry soil and dung are mixed thoroughly, water is added, and the mix is kneaded to a uniform plastic state. Bricks of the modular size 190 × 90 × 90 mm are moulded in a wooden mould, dried in shade for the first days to avoid shrinkage cracking, and then cured for 28 days (Fig. 1). A small additional group of bricks may be fired at low temperature to compare fired and unfired behaviour, since the reviewed literature shows opposite trends for the two cases [3], [6].

To keep the comparison fair, the following practices are proposed. The same person and the same mould are used for all mixes. The mix is placed in layers and pressed into the corners of the mould, and the top surface is levelled. The wet brick is released from the mould carefully and stacked on edge in shade, away from direct sun and wind, because rapid surface drying causes shrinkage cracks. The bricks are turned periodically so that they dry evenly, and each brick is marked with its mix ID and date of casting.

Soil sieved (4.75 mm)	→	Cow dung sun-dried, sieved	→	Dry mixing 0–20 % dung	→	Add water, mix to plastic state	→	Moulding 190 × 90 × 90 mm	→	Shade dry and cure 28 days	→	Testing IS 3495, IS 1077

Optional: low-temperature firing after drying, for comparison with unfired bricks.

Fig. 1: Process flow for the preparation and testing of cow dung bricks

E. Testing. Five bricks of each mix will be tested for each property, following IS 3495 (Parts 1–3) [7]: compressive strength after 28 days, water absorption after 24 h of immersion in cold water, and efflorescence. Dimensions and dry density are also recorded. The results are compared with IS 1077 [8], which sets a minimum average compressive strength of 3.5 N/mm for the lowest class of burnt clay brick, a maximum water absorption of 20% by mass for classes up to 12.5, and limits on efflorescence. IS 1077 covers burnt clay bricks, so for unfired bricks it is used only as a benchmark. A wet compressive strength after soaking is recommended as an

additional test for unfired bricks, because a large loss of strength on wetting has been reported for dung-stabilised earth bricks even at the best dung content.

The test procedures are outlined below.

- **Compressive strength (IS 3495 Part 1).** Each brick is tested on its flat face in a compression testing machine. The faces are levelled so that load is applied evenly, and the load is applied axially at a uniform rate until the brick fails. The compressive strength is the maximum load divided by the loaded area, in N/mm^2. The average of the five bricks is reported together with the individual values and the standard deviation.
- **Water absorption (IS 3495 Part 2).** Bricks are dried to constant mass and weighed, immersed in clean water at room temperature for 24 h, wiped of surface water and weighed again. Water absorption is the gain in mass expressed as a percentage of the dry mass. Unfired bricks may soften or lose material in water, so any disintegration, loss of mass or surface erosion is noted during the test.
- **Efflorescence (IS 3495 Part 3).** A brick is stood in a shallow dish with water so that the water is absorbed and evaporates, and the white salt deposit on the surface is then rated against the grades of the standard (nil, slight, moderate, heavy, serious).
- **Dry density.** Each brick is dried to constant mass, weighed and measured, and its density is calculated as mass divided by volume. Density is useful for comparing mixes, since it reflects the porosity of the brick.
- **Wet compressive strength.** For unfired bricks, the compressive strength is measured after soaking and compared with the dry value. The ratio of wet to dry strength shows how much strength is lost when the brick is wet.

III. RESULTS AND DISCUSSION

This section summarises what the published studies report on cow dung in bricks and earth blocks, and compares the reported values with the requirements of IS 1077.

A. Mechanism of action. Millogo et al. [2] studied lateritic-clay adobes by X-ray diffraction, thermal analysis and electron microscopy. They proposed that cow dung reacts with kaolinite and fine quartz to form an insoluble silicate amine that binds the soil particles together, and that the fibres in the dung limit the spread of cracks, giving a more homogeneous microstructure with an apparent reduction in porosity. Kulshreshtha et al. [9] later examined the water resistance of cow-dung-stabilised compressed earth blocks experimentally and questioned whether the strongly alkaline conditions assumed in that mechanism are consistent with the pH range of 6.5–9.5 reported for cow dung. The mechanism is therefore still under investigation, but both studies agree that dung improves the behaviour of earth blocks in contact with water.

From a practical point of view, two effects can be distinguished. The first is physical: dung contains fine fibres and organic matter that act as a network inside the soil matrix, reducing the

opening and spread of shrinkage cracks as the brick dries. The second is the effect on water: organic matter in the dung is reported to make the surface of the soil particles and pores less easily wetted, so that the block takes up water more slowly and loses less strength in contact with it. The relative importance of these effects probably depends on the soil, which is one more reason to test the local soil rather than rely on values from other places.

B. Unfired earth blocks. In his study of adobe blocks, Memiru [5] used 5, 10 and 15% cow dung by dry mass of soil and found that loss of material, water absorption and loss of strength after soaking were all lower for dung-stabilised blocks than for blocks stabilised with cement or fibre. Pachamama et al. [4] tested earth mortars with 20 and 40% dung by volume; the higher content gave better durability under water, while the lower content gave greater mechanical and adhesive strength. These results show that the best dung content depends on whether strength or water resistance is the priority. Tamang et al. [6] made earth bricks with cogon fibre and cow dung and measured an average water absorption of 25.38%. They concluded that such bricks suit dry environments only, but estimated their unit cost at about 25% below that of third-class burnt clay bricks.

C. Fired bricks. In fired bricks the dung burns out and leaves pores. In experiments with clay from Kassala, Sudan, in which dung was added at 5–47% by volume, strength and density decreased and water absorption increased as the dung content rose; bricks made by the sand-moulding method were stronger and less absorbent than slop-moulded ones at the same dung content [3]. The same document explains that the pores allow cracks to travel more easily under load and take up more water. Hydrothermally treated cow manure mixed with clay and fired in an electric furnace gave a best result of 1.92 MPa compressive strength, 29.57% water absorption and 1.37 g/cm^3 density, and the effect on strength depended on the type of clay [10]. This value is below the 3.5 N/mm^2 minimum of IS 1077, which shows that dung content and treatment must be chosen carefully. Cow dung ash, a different product, has also been studied as a partial cement replacement in mortar [11].

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Table 2: Summary of reported findings on cow dung in bricks and earth blocks

Ref.	Material / brick type	Reported finding
[2]	Lateritic-clay adobe blocks (unfired)	Water resistance clearly improved; fibres limit cracking; apparent reduction in porosity.
[9]	Compressed earth blocks (unfired)	Experimental study of the water-resistance mechanism; questions the high-pH mechanism proposed in [2].
[5]	Adobe blocks (unfired), 5–15% dung by dry soil mass	Lower material loss, water absorption and strength loss after soaking than cement- or fibre-stabilised blocks.
[4]	Earth mortars (unfired), 20 and 40% dung by volume	40% gave better durability under water; 20% gave higher mechanical and adhesive strength; 72 h fermentation helped.
[6]	Earth brick with cogon fibre and cow dung	Average water absorption 25.38%; suitable for dry environments; about 25% cheaper than third-class burnt clay brick.
[3]	Fired clay bricks, 5–47% dung by volume	Strength and density fall and water absorption rises as dung content increases; sand-moulded bricks better than slop-moulded.
[10]	Fired clay with hydrothermally treated manure	Best result: 1.92 MPa, 29.57% water absorption, 1.37 g/cm^3 density.

D. Comparison with IS 1077. IS 1077 classifies common burnt clay building bricks by minimum average compressive strength, from 3.5 N/mm^2 for the lowest class up to higher classes used in load-bearing and heavy-duty work. It limits water absorption to 20% by mass for classes up to 12.5 and to a lower value for the higher classes, and it limits efflorescence to moderate for the lower classes and slight for the higher ones [8]. Table 3 sets the reported results next to these requirements.

Table 3: Reported values compared with the IS 1077 benchmarks

Property	IS 1077 benchmark [8]	Reported value	Source
Compressive strength	Minimum 3.5 N/mm^2 (lowest class)	1.92 MPa (fired clay with treated manure)	[10]
Water absorption	Maximum 20% (classes up to 12.5)	25.38% (earth brick with cogon fibre and dung)	[6]
Water absorption	Maximum 20% (classes up to 12.5)	29.57% (fired clay with treated manure)	[10]

The comparison shows that the dung-based bricks reported in these two studies do not reach the limits of IS 1077. This does not mean that dung bricks cannot be useful: [6] concluded that their bricks suit dry environments, and an unfired brick is not a burnt clay brick, so IS 1077 is only a benchmark for it. It does show that a dung brick intended for walling must be tested against the requirements of its intended use, and that the values for strength, water absorption and wet strength should be reported together rather than one at a time.

E. Cost and sustainability. Dung is a waste material that is available at little or no cost near farms and cattle sheds, and unfired dung-stabilised bricks avoid the fuel needed for kiln firing.

The cost advantage reported in [6] supports this. Sand–cement blocks, in contrast, have a high embodied energy and are unaffordable for much of the population in developing countries, which is one of the reasons given for developing dung-stabilised earth blocks [2]. Any such saving must be set against the lower strength and higher water absorption of some dung bricks.

In the proposed programme the cost of each mix will be estimated from the cost of the soil, the dung and its collection and drying, the water, labour for mixing and moulding, and, for fired bricks, the fuel. Dividing the total by the number of bricks gives a cost per brick that can be compared with the local market rate of burnt clay bricks. In addition to cost, the environmental benefit of each mix can be described qualitatively by the share of soil replaced by dung and by whether firing is avoided. A quantitative assessment of embodied energy and carbon emissions would need measured fuel data and is left for later work.

F. Selecting the optimum dung content. Because strength usually falls and absorption rises in some systems while water resistance rises in others, the optimum content is a compromise. The following approach is proposed. First, the mixes that meet the minimum strength set for the intended use are retained. Second, among them, those with the lowest water absorption and the smallest loss of strength on wetting are preferred. Third, mixes with visible shrinkage cracks, surface erosion or heavy efflorescence are rejected. Finally, the lowest cost among the remaining mixes decides the choice. If no mix meets the target, the dung content, the moulding method or a small addition of a stabiliser can be revised in a second round of tests, and the original mixes serve as the reference.

G. Possible applications. Depending on the results, unfired dung bricks may be suited to non-load-bearing partition walls, boundary walls and single-storey rural houses in dry regions, where cost is the main concern and exposure to rain is limited. In wetter regions a protective plaster, a damp-proof course at the base and a roof overhang would be needed to protect the walls. Fired dung bricks, if the strength is adequate, might serve as lightweight infill, since the pores left by the burnt dung reduce density [3].

H. Limitations and research gaps. Each study reviewed used its own soil, so results cannot be applied directly to other soils. Several sources are theses and technical briefs rather than peer-reviewed papers, and the dung content is expressed by mass in some studies and by volume in others, which makes direct comparison difficult. Long-term durability under repeated wetting and drying, thermal performance, and the effect of dung from different animal diets remain insufficiently studied. These gaps are the reason for the experimental programme proposed in this paper.

The proposed programme also has limits of its own. It uses one soil, so the findings will describe that soil only. Five bricks per mix give a first estimate of the average and the scatter but not a statistical basis for strict quality control. Dung is a natural material whose composition varies with the animal, its feed and the storage time, so a single batch may not represent all batches. The odour of fresh dung and the health aspects of handling it, including the use of

gloves and the drying of the dung before use, should be considered when production is scaled up.

IV. CONCLUSION

This paper reviewed published work on cow dung as an additive in bricks and earth blocks and proposed a mix design and test programme for a sustainable brick. The reviewed studies show that cow dung can improve the cohesion, crack resistance and water resistance of unfired earth blocks and can lower the cost of the brick, while in fired bricks higher dung contents raise porosity and water absorption and reduce strength. Some reported dung bricks do not reach the minimum strength and water absorption limits of IS 1077, so the dung content, moulding method and curing or firing conditions have to be chosen with care. The proposed mixes with 0 to 20% dung, tested for compressive strength, water absorption and efflorescence according to IS 3495, will allow the optimum content for the local soil to be identified. Wet strength, long-term durability and thermal performance should be studied next.

V. FUTURE SCOPE

The work can be extended in several directions. Other soils and other dung contents can be tested to see how far the findings carry over. A small addition of lime or cement could be examined as a way to raise the wet strength of unfired bricks while still keeping most of the dung. Repeated wetting-and-drying and freeze-thaw-type cycles, as well as long-term exposure to rain, would show how the bricks age. Thermal conductivity tests would show whether dung bricks improve the comfort of low-cost houses. Finally, a life-cycle comparison of energy and emissions against fired clay bricks would put the sustainability claims on a measured basis.

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