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ORIGINAL RESEARCH PAPER

Feasibility study on the development of fly ash bricks utilizing vermicompost as an alternate material for M sand

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ABSTRACT

Raw materials requirement is foremost necessary in construction sector. Due to the increase in construction activities, the raw material utilization is also increased, which may lead to depletion of the resources. The usage of M sand also increases day by day. On the other side, waste disposal is posing a major threat to environment and human health. This paper shows the investigation carried out in manufacturing fly ash bricks made by utilizing vermicompost as an alternative material for M sand, the physical and chemical properties of M sand and vermicompost are studied and they seem to be the same. In this study, an attempt is made to check the feasibility of replacement of vermicompost for M sand in brick making. The brick specimens are casted as per the mix proportions and they are tested for strength and durability at the age of 28 days. It has been identified that the vermicompost replacement at 5% and 10%, the compressive strength of the brick is 7.90 and 7.31% respectively, which is found to be nearer to the strength of the control specimen and the water absorption for all the mixes of the brick casted were below 20% as per IS code. Inclusion of vermicompost in the fly ash bricks will tend to reduce the use of M sand.

KEYWORDS

bricks, fly ash, M sand, vermicompost, strength, durability

1. INTRODUCTION

Research studies are carried out by utilizing waste materials and industrial by-products such as fly ash, waste water sludge ash, municipal solid waste, etc., in the manufacturing of bricks [1–3]. In recent past, fly ash was considered as one of the prominent materials in sustainable building construction. Fly ash is a by-product obtained from the thermal power plant stations and it is also widely utilized in the manufacturing of light weight bricks and considered better in terms of strength when compared with the conventional clay bricks. The fly ash bricks are light in weight and less costly than clay brick thus they are considered economic to use in construction [4]. The high amount of calcium oxide present in the fly ash makes it suitable for use in the construction for pillars, foundation and also in the construction of walls [1] Development of bricks by using bottom ash and fly ash is considered a more feasible solution than the conventional clay bricks because of its lower cost, eco-friendly and increase in the strength [2]. Bricks manufactured from fly ash obtained from coal industry and it is replaced for clay at various percentages with fly ash, have higher compressive strength than the clay bricks with 20% strength enhancement as per Pakistani codes [4]. Fly ash bricks manufactured with partial replacement of cow dung ash and wood ash possessed maximum strength at 5% and 15% of cow dung ash and wood ash respectively [5]. The

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strength of the bricks increases with the increase in the amount of fly ash and bottom ash in the bricks [6].

In addition to fly ash, many sustainable materials are used in building construction. Eliche-Quesada et al. [1] in their study used various organic materials such as saw dust, marble residues, compost in the manufacturing of bricks and have concluded that it is possible to produce ceramic bricks incorporating these wastes and the strength can be attained equal to that of the clay bricks. Karthigai Priya et al. [7] studied the properties of compost and compared it with that of red soil and had shown that compost can be used as a replacement for red soil in brick manufacturing. Also, they studied and provided the micro structural characteristics of compost and red soil by scanning SEM (scanning electron microscope), EDAX (element distribution analysis), and XRD (X-ray diffraction). It is found that the compost has a dense and compact microstructure and it reduces the porosity in the material. Lightweight fired clay bricks manufactured with rice husk ash is found as potential raw material in brick manufacturing and especially 2.5% addition of rice husk provided more strength to the bricks [8].

This paper focuses on manufacturing of fly ash bricks by utilizing compost as one of the raw materials. On daily basis, household wastes are increasing day by day because of population increase, thus creating major pollution to land and the environment. Compost is a sustainable material obtained by the conversion of these wastes and in this study, it is replaced for M sand at percentages of 0–20% with 5% increment for the production of bricks. Firstly, to understand the feasibility of utilizing the compost for M sand the physical and chemical characteristics of the materials are tested and compared. The micro structural analysis namely Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis is carried out for compost and M sand. Then bricks specimens are manufactured by replacing compost for M sand. The mix proportion for the bricks are derived from the past research studies and bricks were prepared with 5%, 10%, 15%, 20% vermicompost for M sand. The bricks were then compared with the control fly ash bricks. The strength and durability tests are carried out as per standards for the casted specimens.

2. EXPERIMENTAL METHODS

2.1. Materials

The materials used in this study are fly ash, cement, M-sand and compost for manufacturing bricks. The cement used is Ordinary Portland Cement of grade 53. The M sand and fly ash is collected from the local area where the study is carried out. The compost used in the study is obtained from the compost plant of the university campus, where the food waste and the yard waste are collected from hostels and main blocks of campus. The waste is decomposed by bacteria for one week and then the next week the earthworms are used to convert it into mature compost. The physical and chemical characteristics of the raw materials are carried out as per IS standards.

2.2. Manufacturing of bricks

The mix proportions adopted in the manufacturing of the bricks are given in Table 1. The mix proportion for casting the fly ash bricks is arrived by referring past studies [6] and on a discussion in the field site. A total of 10 proportions were taken in this study and the bricks are casted as per the proportions given in Table 1. The proportions for specimen 1 to 5 are first casted on an experimental basis and they are tested at 7 days for determining the compressive strength. From the results, it is observed that the specimens failed in compression. Then the percentage of cement is increased and next set of proportions is derived for the experimental study. Specimen 6 to 10 in Table 1 shows the second set of proportion adopted after increasing the cement content.

The fly ash, cement, M-sand and vermicompost are measured as per the proportion mentioned and it is first mixed in dry state and then the water is added to it and mixed well till there is absence of lumps in the mixture. The size of the brick adopted in this study is 23x11x7 cm. The prepared mixture is poured into the brick mould in three layers and each layer being compacted 25 times in order to reduce the pores present inside. Also, the mould is placed in a table vibrator in order to compact the mixture mechanically. Then the specimen is kept at room temperature for 24 h and then it is demoulded and set into the curing tank. The specimens are cured for a period of 7 and 28 days and then they are tested for their strength and durability. The casting of the specimens is shown in Fig. 1.

2.3. Testing

Initially the physical properties of the raw materials are studied. The physical properties such as specific gravity, fineness modulus and water absorption of the raw materials

Table 1. Mix proportioning of fly ash bricks

S. No	Specimen No	Cement (%)	Fly ash (%)	M-sand (%)	Vermicompost (%)
1	1	8	49	43	0
2	2	8	49	38	5
3	3	8	49	33	10
4	4	8	49	28	15
5	5	8	49	23	20
6	6	11	46	43	0
7	7	11	46	38	5
8	8	11	46	33	10
9	9	11	46	28	15
10	10	11	46	23	20

Fig. 1. Casting of the specimens

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are carried out and the results are evaluated. The elemental composition is carried out for M sand and vermicompost by Energy Dispersive X-Ray Analysis (E-DAX) supplemented with the Scanning Electron Microscope (SEM). The micro-structural images for the same are carried out by Scanning electron Microscopy usingScanning Electron Microscope EVO 18 (CARL ZEISS). The physical tests such as colour, shape and size are carried out as per IS standards. Generally, the colour of the bricks should be dark in grey as in the case of the fly ash bricks. The shape and size of the brick should be rectangular in size with sharp edges. The compressive strength test is carried as per the IS standard to determine the load carrying capacity of the bricks under compressive load. The specimens at the age of 7 and 28 days were tested in a compression testing machine of 1,000 kN capacity. To check the durability properties, water absorption test, soundness test, hardness and impact tests are carried out. In water absorption test, the brick specimens are immersed in water for a period of 24 h and then the increase in weight is calculated. The weight should not be more than 20% of the initial weight. The lesser the water absorption, the higher the durability of the bricks.

The soundness of the bricks is tested by striking two bricks with each other and it should give a clear bell sound and the bricks should not break. The hardness of the bricks is tested by scratching it with a hard nail or with a finger and there should be no scratches or impression left on the bricks. In the impact test, bricks are dropped from the height of 1 m and should not break. The lower the impact factor, the higher durability of the bricks.

3. RESULTS AND DISCUSSIONS

3.1. Physical characteristics

The physical appearance of M sand and vermicompost is found grey in colour and brown in colour respectively. The appearance of the fly ash is found to be light grey and the cement is grey in colour. The values of specific gravity for M sand and vermicompost is 2.33 and 1.76 respectively and the fineness modulus for M sand and vermicompost is found to be 4.51 and 1.77 respectively. For cement and fly ash, the values of specific gravity are 2.22 and 2.06 respectively. These results are shown in Table 2. From the results obtained, it is noted that the compost has a less fineness modulus than M sand indicating that it is finer than M sand. The water absorption for M sand and vermicompost are 4.35% and 2.3% respectively. It is found that the water absorption of compost is very much less than that of M sand, so that the durability properties are expected to improve when using this material for M sand. The particle size distribution graph for compost and M sand are represented in Figs 2 and 3 respectively.

Table 2. Physical properties of raw materials

Details	Specific gravity	Water absorption (%)	Fineness modulus (%)
M-sand	2.33	4.35%	4.51
Vermicompost	1.76	2.3%	1.77
Cement	2.22	–	–
Fly ash	2.06	–	–

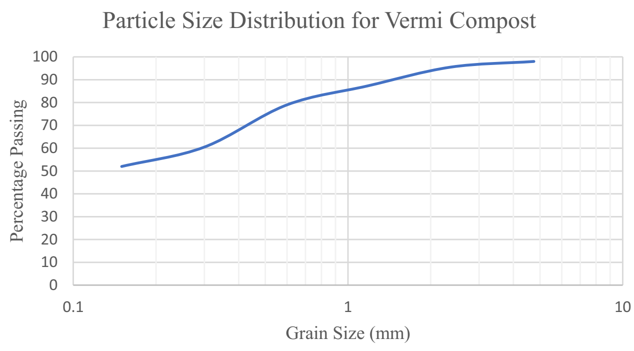

Fig. 2. Particle size distribution for vermicompost

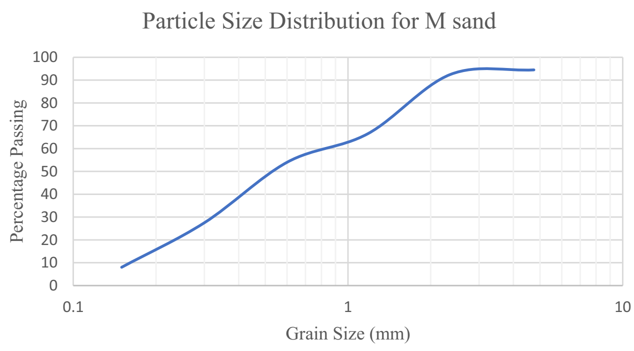

Fig. 3. Particle size distribution for M sand

From the graph it is evident that the compost has finer particles than M sand, therefore these finer particles can fill the pores in the brick matrix thus paving way to reduce the porosity.

3.2. Chemical characteristics

The elemental composition for M-sand and vermicompost are found by Energy Dispersive X-Ray Analysis (E-DAX) coupled with Scanning Electron Microscope. The composition of M-sand and vermicompost in terms of elemental percentage is shown in Table 3.

Table 3. Chemical composition of M sand and vermicompost

Elements	M-sand %	Vermicompost %
C	22.8	37.8
O	41.8	42.0
Na	1.5	0.9
Mg	2.9	1.1
Al	4.4	3.8
Si	13.3	8.3
P	–	0.2
K	1.5	0.9
Ca	4.8	2.0
Ti	0.9	0.4
Fe	6.1	2.6

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From the results obtained, it is noted that carbon, oxygen, sodium, magnesium, aluminium, silica, potassium, calcium, titanium and iron are available in M sand and vermicompost. But the percentage of elements available looks different. For this purpose, it is decided to replace the vermicompost with 5%, 10%, 15% and 20% and the mechanical and durability properties of the bricks are studied. Vermicompost can be substituted for M sand and further testing has been carried out to validate its suitability to use as an alternate material for M sand in brick manufacturing.

3.3. Microstructural characteristics

Scanning Electron Microscopy. The SEM images for M-sand and vermicompost are shown in Figs 4 and 5 respectively.

The above images show the internal structural pattern of M sand and vermicompost. From the SEM micrographs, the pore structure and the pore morphology of the material can be assessed [9]. From Figs 4 and 5 it can be found that the black spots that are seen between the particles are the open pores present in the material. It is observed that, the particles are closely connected and the pores are much fewer in vermicompost [7]. Moreover, the particles are found to be overlapped against each other in vermicompost, which means that the porosity may be lower in vermicompost. This tendency of the compost may improve the quality of the bricks. However, the quality and durability of the bricks can be validated from the durability test results from the bricks only.

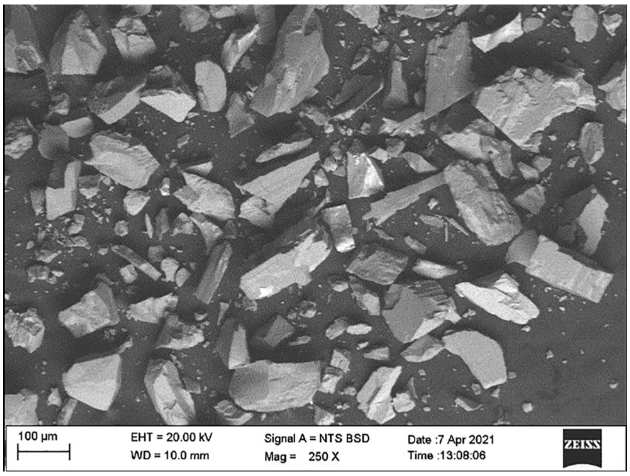

Fig. 4. SEM image of M sand

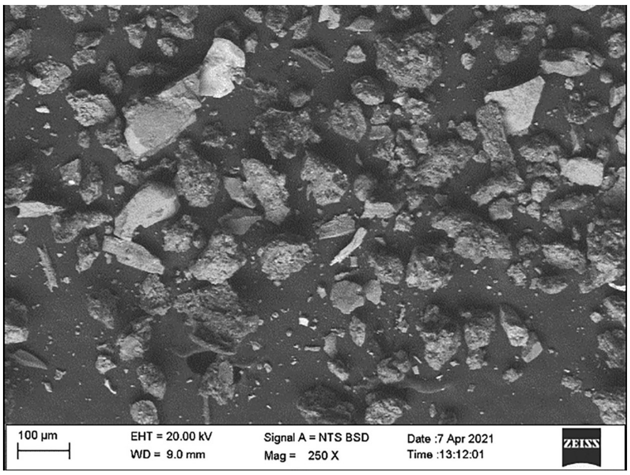

Fig. 5. SEM image of vermicompost

3.4. Compressive strength

Compressive strength for conventional brick ranges generally from 5.58 N/mm^2 to 7.90 N/mm^2 [2]. The compressive strength results of the specimens casted and tested at 7 and 28 days are shown in Tables 4–6. The compressive strength of the bricks at 7 days for specimen 1 to 5 in experiment 1 is very much lower that it failed in compression. So, the cement proportion has been changed and a new experiment 2 is devised based on the past literatures [6], and 7 days compressive strength is found for experiment 2. The results are good and the specimens did not fail in compression. So, this mix proportion has been fixed and the specimens are casted and tested at 28 days of age. Table 4 shows the 7 days strength of the specimens from experiment 1. Tables 5 and 6 show the compressive strength of the specimens at 7 and 28 days of age for experiment 2 respectively.

From Table 6 it can be seen that the compressive strength of the bricks at 28 days of age for the replacement of 5%, 10%, 15% and 20% vermicompost are 7.90, 7.31, 6.32, 5.13 N/mm^2 respectively, which is almost near to the strength of the control specimen (11.85 N/mm^2). When the amount of compost percentage increases, there is a noticeable change in the reduction of strength in the brick. The 7 and 28 days strength values are plotted in a graph and it is shown in Fig. 6.

From the above results it has been inferred that the bricks casted with vermicompost of 5 and 10% replacement showed better results than that of other percentage replacement. When waste materials are added in proportions of 5 and 10%, the expected strength can be achieved up to 8 N/mm^2 [8]. While replacing higher amounts of vermicompost, additional cementitious materials may be added to enhance the strength of the bricks.

3.5. Durability tests

Water absorption. The water absorption test is carried out for the specimens of experiment 2 at 28 days of age. Table 7 shows the water absorption values of the brick specimens casted with vermicompost.

As per the IS code, the water absorption of the bricks should not exceed 20%. From Table 7, it is observed that the water absorption of all the mixes is less than 20% as specified in the IS standards. However, the water absorption of control specimen is less than the water absorption of bricks at 5% and 10% vermicompost replacement. It is observed from

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Table 4. 7 days compressive strength of specimens from experiment 1

Specimen details	Vermicompost%	Cement%	Fly ash%	M sand%	Load in (kN)	Compressive strength in (N/mm^2)
Control specimen	0	8	49	43	100	3.95
V5	5	8	49	38	75	2.69
V10	10	8	49	33	25	0.84
V15	15	8	49	28	Failed	0
V20	20	8	49	23	Failed	0

Table 5. 7 days compressive strength of specimens from experiment 2

Specimen details	Vermicompost%	Cement%	Fly ash%	M sand%	Load in (kN)	Compressive strength in (N/mm^2)
Control specimen	0	11	46	43	200	7.90
V5	5	11	46	38	130	5.13
V10	10	11	46	33	120	4.74
V15	15	11	46	28	50	1.97
V20	20	11	46	23	45	3.95

Table 6. 28 days of specimens from experiment 2

Specimen details	Vermicompost%	Cement%	Fly ash%	M sand%	Load in (kN)	Compressive strength in (N/mm^2)
Control specimen	0	11	46	43	300	11.85
V5	5	11	46	38	200	7.90
V10	10	11	46	33	185	7.31
V15	15	11	46	28	160	6.32
V20	20	11	46	23	130	5.13

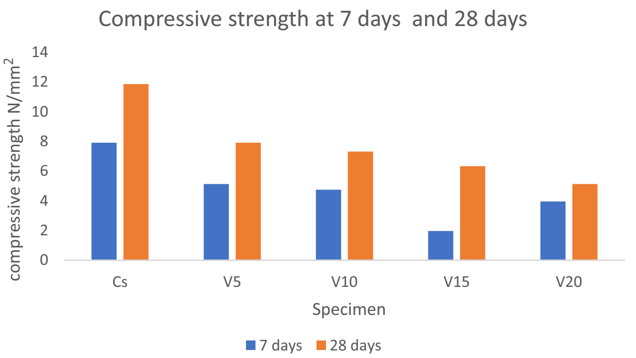

Fig. 6. Compressive strength graph

Table 7. Water absorption of bricks at 28 days

S. No	Specimen	Wet weight (Kg)	Dry weight (Kg)	Change in weight (Kg)	Water absorption %
1	Control specimen	3.730	3.250	*0.48*	12.86
2	5%	3.660	3.150	0.51	16.19
3	10%	3.640	3.120	0.52	14.2
4	15%	3.555	3.115	0.44	12.37
5	20%	3.490	3.090	0.40	11.46

the SEM image that the pore size of vermicompost is small. However, the presence of more of pores may increase water absorption, thereby water absorption of the vermicompost bricks is higher than the control specimen.

Fig. 7. Soundness test

Soundness test. The fly ash brick made with vermicompost gave a clear bell sound when two bricks are struck against each other. It shows that the brick casted is of good soundness and Fig. 7 shows the image for soundness test of bricks.

Hardness test. When the brick is scratched with a hard nail, there is no impression found on the brick. It shows the brick is hard in nature and Fig. 8 shows the test done for it.

Impact test. The impact test is carried out by dropping the brick from a height of 1 m. The brick did not break and it showed good resistance to impact and it is depicted in Fig. 9.

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Fig. 8. Hardness test

Fig. 9. Impact test

Fig. 10. Colour test

Fig. 11. Shape and size test

3.6. Other tests

Generally, the colour of the fly ash bricks is dark grey and the colour of the bricks manufactured by utilizing vermicompost is observed as dark in grey, and it is represented in Fig. 10. The bricks are rectangular in shape and the edges are sharp. So, the shape and size of the bricks are accurate and Fig. 11 shows the shape and size of bricks.

4. CONCLUSION

- This study is focused on manufacturing of fly ash bricks by replacing vermicompost for M sand.
- The physical and chemical characteristics tests are done for the raw material and it has been noted that the elemental composition of compost and M sand looks the same
- The SEM results showed that the microstructure of vermicompost contains fewer pores and it is denser than M sand so that it can be used as a replacement for M sand.
- The physical properties of vermicompost are similar to the M sand.
- From the devised mix proportions, the brick specimens are casted at various percentage replacement of compost for M sand.
- The brick specimens at 28 days age are tested for its strength and durability.
- From this it is observed that vermicompost replacement at 5% and 10% for M sand gave good compressive strength.
- The water absorption of all the specimens is below 20%, i.e. it states that the quality of the bricks manufactured is good.
- So, by utilizing vermicompost in the manufacturing of bricks, the amount of raw material required in making the brick will get reduced, which automatically reduces the overall cost of the brick.
- So, the use of vermicompost in brick manufacturing will not only reduce the usage of M sand but also waste management can be done effectively.

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