Characteristic and microstructural study on an alternate material in brick manufacturing

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Abstract. Rapid urbanization leads to diminishing of natural resources that are used in the construction activity thus creating threat to the environment and the society. If this situation exists, it will pose a severe threat to environment in future. Therefore, some alternate measures have to be taken in order to handle this issue. This study is focused on utilizing Vermicompost as a substitute material for Red soil in the manufacturing of bricks. The characteristic test and microstructural tests are carried out for the materials constituting the brick. The physical properties are tested by specific gravity and particle size analysis. In addition to this the microstructural studies of the brick making material and Vermicompost are done by Scanning Electron Microscope (SEM), Energy Dispersive Infrared Spectrometer (EDAX) and X-Ray Diffraction (XRD). The results of SEM show that the particles of Vermicompost is less porous and has lesser water absorption than that of red soil. From the XRD results it is evident that the elements obtained for the peak values of Red soil and Vermicompost are nearly same and also these elements are responsible for the good quality of bricks. It has been noted that the physical and chemical properties of the Vermicompost match with that of the Red soil indicating that it can be used as a replacement for Red soil. The manufactured bricks will be cost effective as well as sustainable solution in construction sector.

Keywords: Red soil, Vermicompost, Bricks, Micro structural Characteristics, Comparison

1. Introduction

Brick is considered as an important construction material since many years ago. The main factors used for assessing the manufactured bricks are its quality and durability so that to use in construction [1]. The bricks with higher porosity have more tendency to lose its durability and it has also been verified experimentally by researchers. Therefore, porosity is also an important parameter that needs consideration while determining the durability of the bricks [2]. The porosity varies with the type of Clay used in the manufacturing process and also it directly affects the mechanical and durability property of the bricks [3,4]. The microstructural study helps to understand the properties of the material in a more detailed way. The most common methods used for the microstructural study was Scanning Electron Microscope (SEM) and X – Ray Diffraction (XRD) [5]. Apart from this, the
compressive strength is also an important property that needs consideration and it has direct impact on the mechanical property of bricks [6,7].

In recent past there is a growing interest towards utilization of sustainable material for brick manufacturing [5-7]. Compost was utilized in brick manufacturing at various percentages and all the physical, mechanical, durability and microstructural tests are carried out [10]. Before utilizing a particular kind of waste in brick manufacturing there is a need to identify the physical and chemical characteristics of the material and its suitability of replacing for manufacturing of bricks [8]. Utilizing wastes in building materials will bring out many advantages such as improved durability, contributing additional strength and give benefits to the society by adopting sustainable waste management option [9]. The Red soil is one of the largest groups of soil found in our country. It had wide variety of applications and one among them is it was used in the manufacture of bricks. Due to over utilization, the Red soil is also becoming scarce these days. In this paper an attempt is made towards investigating the basic characteristics and micro structural characteristics of vermicompost for the replacement of red soil. The various physical and chemical characteristics studies have been made for red soil and vermicompost and comparison is made between the two for effective replacement. Physical characteristics of the two materials are verified by basic properties such as particle size analysis, specific gravity. In addition to this, micro structural characteristics of two materials are analyzed using SEM. The chemical characteristics of the materials were analyzed using EDAX (Energy Dispersive X – Ray Analysis) and XRD techniques. This characterization study will give prior understanding and give an idea of replacing suitable sustainable materials for brick manufacturing.

2. Materials and methods

The materials generally used in the manufacturing of bricks include Clay, Red soil etc. The aim of this study is to find an alternative material for brick manufacturing. Vermicompost is chosen to test whether it is suitable for replacing Red soil.

2.1. Materials

The materials used in this study for manufacturing bricks are Red soil, Vermicompost and Clay respectively. All these materials are locally available in the study area. In this study particularly the Red soil and Vermicompost will be compared for its properties so as to find a suitable alternative material for red soil. Vermicompost is a by – product that is obtained by the decomposition of municipal solid waste containing vegetable matter and other wastes that are decomposable by earth worms. The Vermicompost used in this study is obtained from the university campus Vermicompost plant. The waste that are generated inside the campus is been converted in to Vermicompost. Clay is also a type of soil that is available in nature and finds its use in large applications especially in the manufacturing of bricks.

2.2. Methods

The main test carried out to characterize the physical property is specific gravity and particle size distribution for Red soil and Vermicompost. Based on these two test results, a comparison will be made between Red soil and Vermicompost. For Clay, liquid limit and plastic limit tests are conducted. The elemental composition of all the materials in the study was carried out by Energy Dispersive X – Ray Analysis (EDAX). The microstructural study was carried out by Scanning Electron Microscopy (SEM) using Scanning Electron Microscope EVO 18 (CARL ZEISS) for identifying structure for identifying the material property. The X – Ray Diffraction (XRD) is obtained from X – Ray Diffractometer D8 Advanced ECO XRCID systems with SSD160 1D detector. The peak values for all the samples are obtained for 2 Theta value from (0° to 90°) in XRD and it is analyzed using JCPDS software to determine the various elements corresponding to various peaks obtained from the XRD analysis.
3. Results and Discussions

3.1. Physical Property

The physical appearance i.e. colour of Red soil and Vermicompost was found to be Red and Brown respectively whereas the appearance of the additional material Clay is also Brown in colour. The values of specific gravity for Red soil and Vermicompost was 2.67 and 1.90 respectively. For Clay, the liquid limit and the plastic limit of the Clay was 57% and 29.52% respectively which signifies that the Clay has high plasticity. So, obviously the water absorption will also be higher. And also, the trend line equation is plotted to find the water content required for the Clay used in the study and it is represented by, \( w = -0.0982N + 58.181 \) (Where \( w \) is the water content & \( N \) is the No. of Blows given while performing the liquid limit experiment).

3.2. Chemical Composition

The elemental composition of the materials used in the study are found by Energy Dispersive X–Ray Analysis (EDAX). The composition of the Red soil, Vermicompost and Clay are presented in Table 1 and also it compares the percentage composition of various elements present in the materials used in the study.

| Element | % Composition |
|---------|---------------|
| Red Soil | Vermicompost | Clay |
| C       | 6.7 | 19.9 | 38.4 |
| O       | 49.3 | 49.4 | 43.5 |
| Na      | 3.5 | - | - |
| Mg      | 1.2 | 1.7 | 0.8 |
| Al      | 10 | 4.8 | 3.7 |
| Si      | 17.5 | 13.6 | 8.9 |
| K       | 0.8 | 1.0 | 0.7 |
| Ca      | 4.8 | 4.7 | 0.9 |
| Ti      | 0.8 | 0.6 | - |
| Fe      | 5.3 | 3.9 | 3.2 |
| Mo      | - | 0.3 | - |
| Cl      | - | 0.3 | - |

From Table 1 it can be seen that the composition of elements such as O, Si, K, Ca for Red soil and Vermicompost are nearly same which indicates the elemental composition of the two materials are moreover same.

3.3. Particle Size Distribution

The particle size distribution or the gradation curve is plotted for both the Red soil and the Vermicompost and then the gradation of Vermicompost is compared with the gradation of Red soil. Then the Uniformity coefficient \( (C_u) \) and the Coefficient of Curvature \( (C_c) \) is calculated for Red soil and Vermicompost. For Red soil the values obtained are \( C_u = 6.1 \) and \( C_c = 0.61 \) whereas for compost the values obtained are \( C_u = 3 \) and \( C_c = 0.9 \) and both these are categorized as poorly graded soil as per IS 1498:1970. The graphs representing Red soil and Vermicompost are shown below in Figure 1 & 2 respectively. It is found that almost the two materials are distributed uniformly from 0.1mm to 5mm size particles. Therefore, the porosity of both the samples will be nearly same. The shape of the graph also looks almost same.
Figure 1. Particle Size Distribution of red soil

Figure 2. Particle Size Distribution of Vermicompost

3.4. Scanning Electron Microscope Analysis (SEM)

The SEM images of Red soil and Vermicompost are shown in Figure 3 & 4 respectively. The structure of the soil and their pattern can be seen from Figure 3 and 4. Porosity and water absorption are the two main property that is discussed from the SEM images observed.
From the above images it can be seen that the black spots that are seen between the particles are the open pores that are present in the material. It is observed that the particles are very closely connected and the pores are very less in Vermicompost when compared with that of Red soil indicating that the structure of Vermicompost is relatively densified [8]. Moreover, the particles are found to be overlapped against each other in Vermicompost which means that the porosity is very less in Vermicompost. Due to this nature of Vermicompost, when it is added as replacement for Red soil, it will fill the larger pores present in it and thus reduce the water quantity required for them [9]. Also due to this overlapping nature which is seen in Fig. 4, it can be said that the binding nature is very good in Vermicompost. Therefore, the water absorption of Vermicompost is very less when compared with Red soil. So, it can be ideally used as a replacement material for Red soil.

The Fig. 5 represents the SEM image of Clay soil. Clay is also partially used in the manufacturing of bricks, so the microstructure of Clay is also studied. From the above image it is observed that that the Clay is more porous with the presence of the black spots. So, the water requirement is higher for this material indicating that the Clay has higher water absorption.

3.5. X-Ray diffraction analysis (XRD)

The XRD patterns of Red soil and Vermicompost are shown in Figure 6 & 7 respectively.
The curve with high intensity peak indicates the presence of highly crystalline element [3, 7]. The elements such as Si, C, Al are common between the Red soil and Vermicompost especially the silica content is rich in both the samples as silica is an important element that plays a major role in quality of bricks and also it is responsible for preventing cracks and shrinkage in the bricks [18]. The next major element present in brick after silica is Alumina, which imparts plasticity to the bricks [18]. From Figure 6 & 7 it is found that the element Alumina is also common in both Red soil and Vermicompost. The significant elements that are responsible for achieving strength for bricks are also present in Vermicompost. From this it is evident that the Vermicompost can be ideally used as a replacement material for Red soil.
The Clay is also a prime material used in the manufacturing of Bricks. The Fig. 8 shows the XRD pattern of Clay. It is to be noted from Figure 7 and 8, some of the elements like Ca and Mg is present in vermicompost and Clay whereas it is not available in Red soil. From Figure 8 it is understood that Si, C and Al is present in Clay minerals which is more significant in the bricks [17].

4. Conclusions
This study is mainly focussed with the characteristic test and the microstructural analysis of the materials used in brick manufacturing. The various conclusions drawn from the study are as follows,

- The materials used in this study are Red soil and Clay whereas Vermicompost can be replaced at various percentages for red soil.
- The particle size distribution drawn for the Red soil and Vermicompost reveals that the gradation of both are nearly same and also the both the materials comes under same category of poorly graded soil obtained from IS 1948: 1970 which indicates that the Vermicompost can be replaced for red soil.
- With Energy Dispersive X – Ray Analysis (EDAX), the elemental composition is arrived for Red soil, Vermicompost and Clay. The percentage composition of some elements like Si, Ca, O are nearly same for Red soil and Vermicompost.
- Scanning Electron Microscopy (SEM) and X – Ray Diffraction (XRD) are the studies carried out to study the microstructural property of the soil samples. From the SEM images it is evident that the particles of Vermicompost are well bonded and it is less porous than the Red soil. When replaced with Red soil it will also reduce the water absorption too. From the XRD graphs, the elements such as Si, Al required for good quality bricks are found to be common in Red soil and Vermicompost.
- From these all results, it is evident that the Vermicompost can be effectively replaced for Red soil at various percentages and further properties of bricks can be experimented by casting bricks with incorporating Vermicompost in it.

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