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Experimental studies on the microstructural, physical and chemical characteristics of building derived materials to assess their suitability in ground improvement

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HIGHLIGHTS

- Application of building derived materials in ground improvement is proposed.
- The technique is evaluated on the basis of several laboratory experiments.
- Depending on the soil, proposed technique can be adopted with suitable judgement.
- Concrete-based building derived material performs better than brick-based ones.

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ABSTRACT

Construction and demolition (C&D)[1] wastes consist of debris generated during the construction and demolition of structural elements. Rapid urbanization renders it necessary to reduce the consumption of non-renewable natural resources drastically and also to limit the dumping of these materials after the expiration of their service life. The primary components of C&D wastes are building derived materials[2] (BDM) composed of rejected concrete and brick from construction and demolition sites. This study investigates and compares the potential for two different kinds of BDM in their virgin state for the purpose of improving the compaction and shear properties of soft soil having low bearing capacity. BDM are collected separately from demolition of brick walls containing cement-mortar as binder and also from demolition of plain concrete blocks. In the first step, these two types of BDM are compared on the basis of their resistance to impact or crushing loads. Then, the BDM are immersed in separate solutions of seawater, sulfuric, hydrochloric, and nitric acid solutions individually and their responses are determined. Concrete based BDM[3] (CBDM) shows greater resistance to impact or crushing, compared to brick based BDM[4] (BBDM). Moreover, in presence of chemicals, CBDM shows greater resistance to weathering. Hence, for the purpose of ground improvement, CBDM is considered. Soil is partially replaced with different percentages of CBDM and the optimum soil-CBDM combination is found, based on compaction characteristics. This approach intends to prevent the dumping of any kind of BDM as solid waste and also provide an economic option to enhance the properties of soil. In this study, the chemical and physical properties of CBDM, BBDM, and soil are investigated separately. Mineralogical analysis through X-ray diffraction (XRD), and microstructural analyses through scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDS) are conducted for CBDM, BBDM, soil, and soil + CBDM mixes. Compaction studies show that the optimum replacement of soil by CBDM is in the range of 17–23% by mass. However, there is a possibility of the presence of aggressive chemicals in soils near the vicinity of water bodies or chemical treatment plants. In order to test the compatibility of the CBDM in such soils, the properties mentioned above are re-evaluated after exposing the CBDM to aggressive chemical environments. Results indicate that virgin CBDM has suitable load carrying capacity,

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[1] C&D – Construction and Demolition.
[2] BDM – Building Derived Materials.
[3] CBDM – Concrete based BDM.
[4] BBDM – Brick based BDM.

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but this capacity decreases after exposure to chemicals. This is associated with change in physical and chemical characteristics of the CBDM, as assessed through XRD, stereomicroscopic imaging, and determination of change in weight. Although the overall performance of CBDM is better than that of BBDM, proper judgement is necessary for their practical application of any kind of BDM for ground improvement depending on location or site conditions.

1. Introduction

Huge volumes of construction and demolition (C&D) wastes are generated due to rapid urbanization, development of infrastructure, and periodic renovation and modification of these structures. These C&D wastes include a significant amount of solid demolition waste due to natural calamities like earthquakes [1]. The United States Environmental Protection Agency (USEPA) defines C&D wastes to consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges [1]. It is necessary to drastically reduce the consumption of non-renewable natural resources and limit the dumping of C&D wastes so as to reduce the contribution of the construction industry in environmental imbalances. The primary component of C&D wastes is building derived materials (BDM). Several researchers have investigated the use of different kind of C&D waste materials in varied engineering applications due to the shortage of natural aggregates and also to arrive at an economic alternative [2]. Recycled sand and brick C&D wastes have been used for production mortars with increase in flexural and adhesive strength and decrease in permeability [3]. Studies on the geotechnical properties of recycled concrete aggregate (RCA) showed that the CBR values are satisfactory for pavement applications [4]. Fine recycled glass (FRG) showed lesser values for water absorption compared to RCA, whereas hydraulic conductivity was higher for FRG [5,6]. The particle size distribution curves for the aggregates made out of C&D wastes were consistent with the requirements of typical aggregates in civil engineering applications indicating their suitability in civil engineering applications such as pavement subbases/bases and footpaths [7]. Subsequently, the use of reclaimed asphalt pavement (RAP) resulted in greater load carrying capacities in pavement base and subbase applications, as compared to RCA and crushed brick (CB) wastes in all cases with the same cement content and under the same curing duration [8]. However, CB, RCA, and waste rock have all exhibited bell-shaped compaction curve typical to that of coarse-grained materials and can be used in place of natural aggregates in engineering applications [9]. The refinements of C&D wastes or BDM incur extra cost due to chemical and mechanical processes associated with them and there are difficulties associated with establishing waste management and recycling plants [10,11,12]. For example, the state of Delhi in India alone generated 1.5 million tonnes of debris from 2009–2014 [13]. But till date, the existing waste recycling facility at Burari in Delhi is the only one of its kind [13].

The present study investigates and emphasizes on the use of virgin BDM to conserve natural aggregates, to reduce the dumping of solid wastes on landfills, to provide cost and energy benefits. Two different kinds of BDM are considered in this study – concrete-based BDM (CBDM) and brick-based BDM (BBDM). Their mineralogical, microstructural, physical, and chemical characteristics are compared to assess their potential for the purpose of ground improvement.

Due to rapid urbanization, plots of land which were previously considered as marginal are now being used for construction purposes. The quality of soil in these regions is not always capable of bearing heavy loads and hence, ground improvement by economic means has become an essential part of any urbanization process. The conventional method of replacement of soft natural soil deposits with good soil involves high cost when the extent of poor soil involved in the project is more. Ground improvement facilitates the construction of foundations over such weak soil deposits in economic manner. Aggregate impact value (AIV) test shows that CBDM has better resistance to impact or crushing loads, compared to BBDM. Exposure to separate solutions of seawater, sulfuric acid, hydrochloric acid, and nitric acid shows that CBDM has greater resistance to weathering or chemical attacks, as compared to BBDM. So, all the tests related to ground improvement are conducted on soil-CBDM mixtures only. The results obtained from specific gravity test, water absorption test and aggregate impact value (AIV) test on CBDM are compared with standard results for natural aggregates, owing to the lack of available data for any kind of BDM. X-ray diffraction (XRD) studies and microanalysis through scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) are conducted to identify the chemical composition of the two kinds of BDM and the soil-CBDM combinations. Compaction characteristics are evaluated for the different soil-CBDM combinations to identify the optimum CBDM content. As mentioned earlier, this study compares the responses of CBDM and BBDM to potentially aggressive chemicals in soils from coastal areas or the vicinity of chemical treatment plants. CBDM and BBDM are respectively immersed in separate solutions of seawater, sulfuric acid (5% v/v), nitric acid (5% v/v), and hydrochloric acid (5% v/v) for 7 days. CBDM shows greater resistance to chemical attacks, as identified by stereomicroscopic imaging. AIV tests are repeated on CBDM after exposure to these chemicals to identify their effect on the performance of the CBDM. According to ASCE, there are no global standards for any kind of virgin BDM in geotechnical applications at present [14,15]. Hence, the results obtained from the present study can be used to establish a basis for the practical use of BDM and provide recommendations to prepare standard codes of practice for these materials. The detailed methodology and observations from this study are presented in the following sections.

2. Materials and experimental methods

2.1. Materials

2.1.1. Building Derived Materials (BDM)

BDM used for this study are procured from the Hyderabad campus of the Birla Institute of Science and Technology (BITS)-Pilani. This campus is undergoing extension, and is thus producing huge amounts of BDM. The primary sources of the BBDM are the demolition of some existing structural elements that are no longer serviceable, and hence undergoing renovations. The CBDM are obtained from the concrete cubes, cylinders, and prism specimens which are rejected from the concrete technology laboratory after preliminary testing of concrete mixes, which are being used for the extension of the campus. Based on suggestions from existing literature for the inclusion of foreign materials in soil, the procured CBDM and BBDM are crushed to the sizes less than 10 mm [16].