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Review of Brick Waste in Expansive Soil Stabilization and Other Civil Engineering Applications

Ali Al-Baidhani*[1], Abbas Al-Taie[2]
[1]M.Sc Student, [2]Assistant Professor
Department of Civil Engineering, College of Engineering, Al-Nahrain University, Baghdad, Iraq
***Email:** *al.baidhani7471@gmail.com*

Abstract
The expansive clay soils are spread in a large area all over the world. They are one of the predominated problematic soils which can change their volume and loss their shear strength when they exposed to water. Several methods have been used to mitigate the negative effects of expansive soil on civil engineering structures and constructions. Different materials have been applied in these stabilization methods (physical or chemical stabilization). Wastes from construction and demolition of the buildings are among these materials that used as soil stabilizer agents. This paper presents a critical review on one of construction and demolition wastes materials, i.e. brick waste, which is found in large quantiles. The characterization and utilization of brick waste in stabilization of expansive soil and other civil engineering applications was discussed and presented in this paper.

***Keywords:** problematic soil, demolition waste, brick waste, expansive soil, stabilization*

INTRODUCTION

Expansive clay soils spreads in large area all over the world. The properties of these problematic soils at shallow depth are exhibit volume change from variations in soil moisture due to seepage of water into the soils during rains. These soils contain the clay mineral montmorillonite which is a swell and shrink with the increase and decrease in water content of [1-5]. Damages to the civil structures (e.g., railways, Road network, buried pipe lines, and other lifeline facilities) due to swelling and shrinking problems of soil can be consider as the costliest natural hazard in some countries. The engineering problems resulted from swelling of expansive soils have been investigated and reported worldwide. The estimated annual cost of such problems exceeded £150 million in the United Kingdom and $100 billion in the United States of America, [14, 15]. Expansive soils are complex and variable materials. To improve the engineering properties, performance in building construction, and control swelling-shrinking behavior of these soils, different methods can be used include replacing existing soil with non-expansive soil, maintain constant moisture content and addition of various stabilizers and additives [13, 16].

In recent years, with increasing the demand for raw materials, infrastructure, and fuel; soil stabilization took new approaches. With the development of researches, materials, and equipment; these approaches are emerging as a popular and cost-effective methods for soil improvement with the help of additives from waste materials, including construction and demolition wastes. There are many economic activities generate the wastes of construction and demolition such as deconstruction and demolition of engineering civil works. The reuse of construction and demolition wastes has

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several benefits including reduces the use of natural resources and the landfill of inert materials coming from the construction industry. Engineered soils with high bearing values can be produced using soil stabilizers like the wastes of construction and demolition. This type of stabilizers considers as eco-friendly. Introducing of wastes of construction and demolition as a soil stabilizer helps in solving many environmental problems. The purpose of the current paper is to present the engineering researches concerning different application and uses of one type of these wastes, i.e., brick wastes, as a stabilizing agent for different geotechnical and civil engineering applications.

Characterization and Properties of Brick Waste

Brick waste, in different forms, has been used in many civil engineering applications, it used as aggregate materials, pavement subbase material, filter material in permeable pavements, filling material, as filler in filled pozzolanic cement, and as a fine and coarse aggregates in concrete production. The constitution of this material consisted of aluminosilicate, silica quartz, hematite, and anhydrite [7]. Heikal and El-Didamony, stated that crushed clay materials are act as a pozzolanic material. These materials have high degree of water absorption [12]. The chemical composition of crushed clay bricks is shown in Table 1.

Table 1: *Chemical composition of crushed clay bricks [7].*

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	TiO_2	P_2O_5	H_2O	LOI
63.89	25.49	7.73	0.29	0.04	0.2	0.95	0	0	0	1.33	0.95

Recycling Brick Wastes in Civil Engineering Constructions

The possibility of using recycled brick wastes in various civil engineering constructions have been presented in literatures. In roadbed layers, the crushed brick was used as aggregate materials [17]. The addition of crushed brick improved the maximum density of compacted sub-base material. The experimental investigation of Arulrajah et al., included an evaluation of using recycled crushed bricks as a pavement subbase material [18]. According to this investigation, recycled crushed bricks found to have significant bearing ratio values to satisfy the Australian roadway authority requirements for a lower sub-base material, the addition 65% recycled crushed brick was optimal for usage in pavement subbase applications. Some researchers evaluated the geotechnical and geo-environmental properties of different construction and demolition waste materials included brick waste. Arulrajah et al. were recycled crushed brick in pavement sub-bases [19]. The behavior of crushed brick has shown that this waste material may be improved with additives or mixed in blends with high quality aggregates. The compaction curve of crushed brick is controlled by the surface characteristics and the absorption of this well-graded-material [18-20]. Disfani et al., stated that the blending of 50% of crushed brick with 3% cement produces "cement stabilized blends" with engineering properties satisfies the requirements of roadway authority [21, 22]. Recycled crushed brick in combination with nonwoven geotextile were assessed as filter material in permeable pavements [22]. As a filling material, construction and demolition waste were used as gabion filling materials [23, 24]. In concrete technology, the study of Debieb and Kenai concluded that lower performance of concrete with crushed brick aggregates [25]. These authors utilized crushed brick as aggregates in the production of concrete.

Otoko, presented the laboratory result to show that quality concrete can be produced from crushed demolition waste clay brick (as aggregates), in terms of its tensile and compressive strength [10]. The quality of concrete made of fine crushed brick aggregates are plotted in Fig. 1.

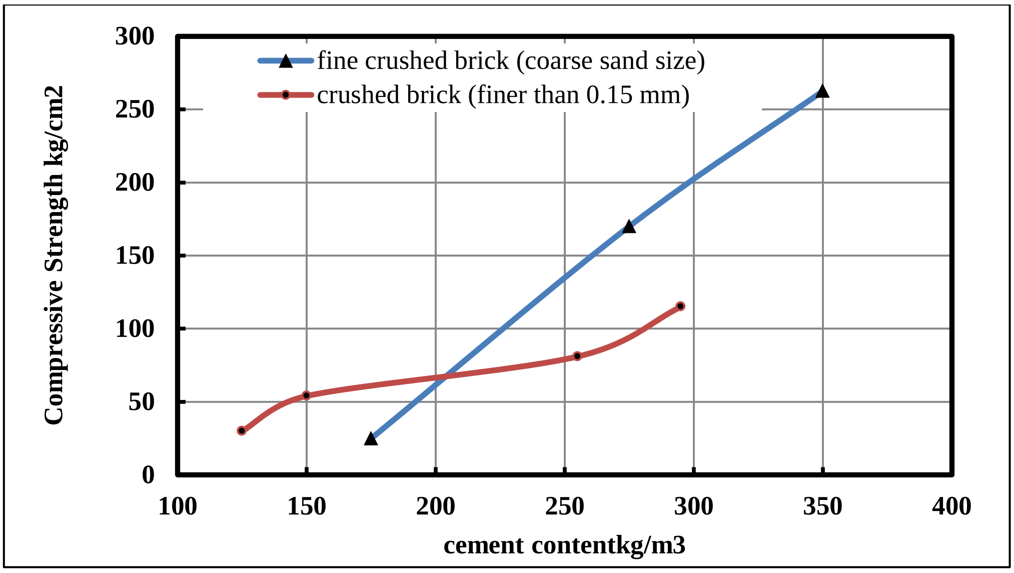

Figure 1: *Compressive strength of concrete made with fine crushed brick (Modified after) [10].*

Recycling Brick Wastes in Stabilization of Soils

Different application and uses of recycled brick waste were presented in the works of researchers. Some of the researchers used the brick waste in the form of aggregates, while the others described the using of dust form of this waste material. The effect of brick aggregate on the properties of expansive soil stabilized with fly ash and lime has been studied by Malhotra and John [8]. The study findings suggested that after a curing period of 28 days improvement of soil achieved the durability and strength to be used as a base course in the pavement. It was observed that the cost is less than conventional base course materials.

Katti and Sankar, investigated the behavior of bearing ratio and strength characteristic of expansive soil mixed with lime and brick aggregates [9]. Their results showed a significant increase in improvement in CBR value of lime- brick stabilization soil compared to lime stabilization one.

A study by Abd El-Aziz and Abo-Hashema, evaluated the effect of using lime and crushed clay bricks or calcined – clay waste stabilization on engineering properties of expansive soil [7]. The results determined that California bearing ratio, shear strength parameters (cohesion (c) and angle of internal friction (Ø)) of soil mixes with additives, generally, increased. While decreasing in swelling, consolidation settlement, soil plasticity and compaction maximum density have been recorded.

Sachin et al, performed a laboratory study on engineering properties of expansive soil treated with burnt brick dust and noticed a significant improvement in these properties (Atterberg's limits, linear shrinkage, compaction characteristics, and swelling properties) [26]. Experiments of these authors were carried out by varying the contents of burnt brick dust (30%, 40%, and 50%). They were noted that the optimum brick dust content 50%, best stabilization effects were obtained at this content. The results indicated that with increase in brick dust, a significant decrease in consistency limits, optimum moisture content, swelling potentials, and shrinkage was recorded. On the other hand, the maximum dry density of stabilized soil was increased on the increment of brick dust. In overall, it was concluded the improvement of expansive soils using brick dust has positive impacts on the soil, such material is environmentally friendly and cost-effective.

Toryila, investigated the behavior of expansive clayey soil stabilized with industrial solid wastes [27]. His study was about the effect of replacement of different materials such as ceramic dust, brick dust, polyvinyl waste, copper slag, sawdust and fly ash and red mud on the engineering properties of soil. Engineering laboratory tests include Atterberg limits, California bearing ratio and compaction test were conducted on soil/solid wastes mixtures. The results indicated that brick dust and almost all the industrial wastes have the ability to enhance the expansive soil, from the economic analysis, these mixtures have low cost compared to conventional virgin soil.

Lakshman et al. improved the engineering properties of black cotton soil by "burnt brick dust" [6]. High dust contents have been used in their study, (30, 40, and 50) %. These authors noticed a considerable reduction in the swelling of black cotton soil, as the content of "burnt brick dust" increased, more reduction was noticed. The optimum "burnt brick dust" content was found 50%. Atterberg limits, linear shrinkage, and compaction water content of soil stabilized with "burnt brick dust" was decreased with increasing the dust content.
Brick Kiln Dust or BKD have been used as a stabilizer for expansive soil under the CBR value by about 135% in pavement in Ganapathy area in Coimbatore city [28]. It was found that California bearing values for roadbed (subgrade and sub-base) is improved by the addition of these cost-savings and eco-friendly material.

Effect of combinations of brick kiln dust and fly ash on geotechnical properties of black cotton soil has been studied by Wanare [29]. Soil samples were treated with varying the percentages of (10%, 20%, 30% and 40%) of brick kiln dust and fly ash with black cotton soil. it was observed that the liquid limit for soil and fly ash mixture is found to be slightly higher than that of soil and brick kiln mixture.

Slightly higher values of plastic limit were recorded for soil-fly ash mixtures (up to 30% of fly ash). On the other hand, soil-fly ash mixtures exhibited higher shrinkage limit values than soil-brick dust mixtures. Also, it was noticed that MDD is constant for all combinations while the optimum moisture content was found to be varying in the mixture of soil brick kiln dust and fly ash. It is higher at 30% of brick dust and 20% of fly ash. Furthermore, the results indicated that brick kiln dust and fly were improved the expansive properties and California bearing ratio of soil.

Reddy et al. performed a study on engineering properties of lime-stabilized expansive soil and brick powder mixture as subbase material in flexible pavements and noticed a significant improvement in engineering properties such as Atterberg's limits, compaction, CBR and swelling [30]. The proportions of lime-stabilized expansive soil to brick powder were (0% to 20%), (60% to 40%), (40% to 60%), and (20% to 80%). It was noticed that mixture of 20% brick powder and 80% lime-stabilized expansive soil increased in

comparison with lime-stabilized expansive

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soil. The final conclusion of this study showed that mixing brick powder and lime-stabilized expansive soil can be considered to be good ground improvement technique especially as subbase material in flexible pavements.

Demolished brick waste has been used as an additive to cohesive soil [31]. The engineering properties of soil were investigated experimentally by carrying compaction test, California bearing ratio test, and unconfined compression test. Experiments were carried by varying the percentages of demolished brick waste, (10, 20, 30, 40 and 50) %. Based on the standard compaction test, 40% of DBW is the optimum content at which the bearing ratio and the compressive strength of soil reached their maximum values.

Saand et al. examined the stabilization of clayey soils using Brick Kiln Waste, BKW [11]. They were found that the addition of BKW made the clayey soils more course and reduced the dry density and soil cohesion, while the angle of internal fiction and ultimate bearing capacity increased with addition 40% of BKW. In over all, the effect of addition of brick waste on soil properties are illustrated in the following figures. Fig. 2 shows that Atterberg limits of cohesive soils mixed with different dosages of brick waste are reduced. The effect of brick waste on soil compaction properties is shown in Fig. 3. It is shown that the optimum water content of soil mixed with brick waste exhibit a sporadic behavior, in some studies, its values were increased, while in others it seems unaffected. On the other hand, the addition of brick waste decreases the density of compacted soil to different degrees. A significant effect of brick waste on dry soil density can be seen at low dosage, 5%. Beyond this percent, the dry density comes to increase, but the final resultant density is lower than the that of virgin soil. Fig. 4 presents the variation of CBR values of soil-brick waste, as shown, as the brick content increased, the CBR values increased up to optimum content, after that they tend to decrease. The optimum brick content is varied from 5% to 20%. The swelling of soil is improving with increasing brick material content, Fig. 5. For further increasing brick waste content, further reducing in swell was recorded.

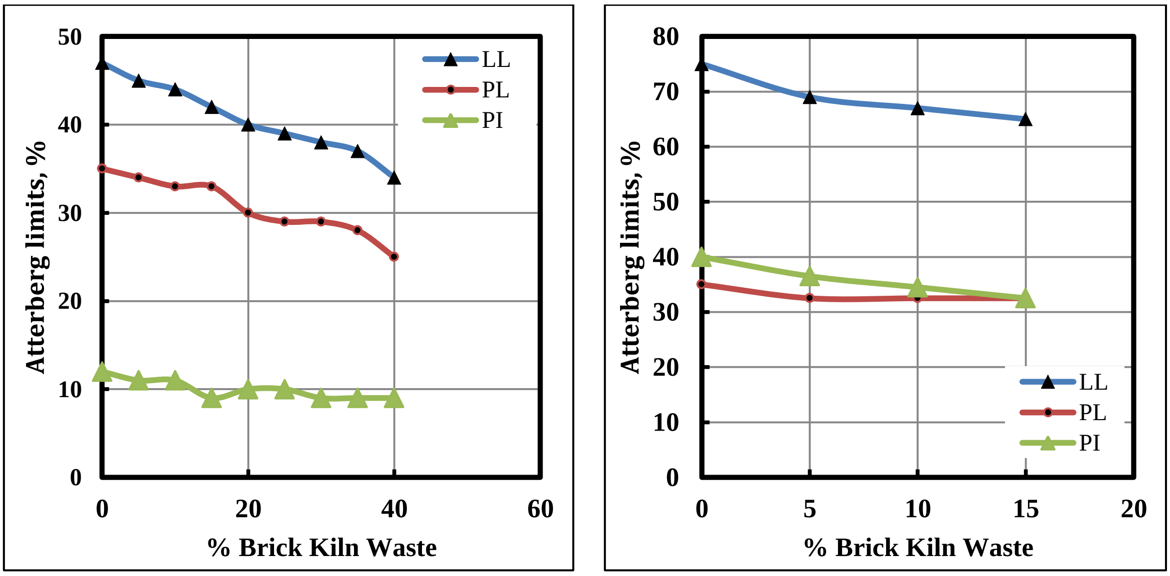

Figure 2: *Effect of brick waste on Atterberg limits.*

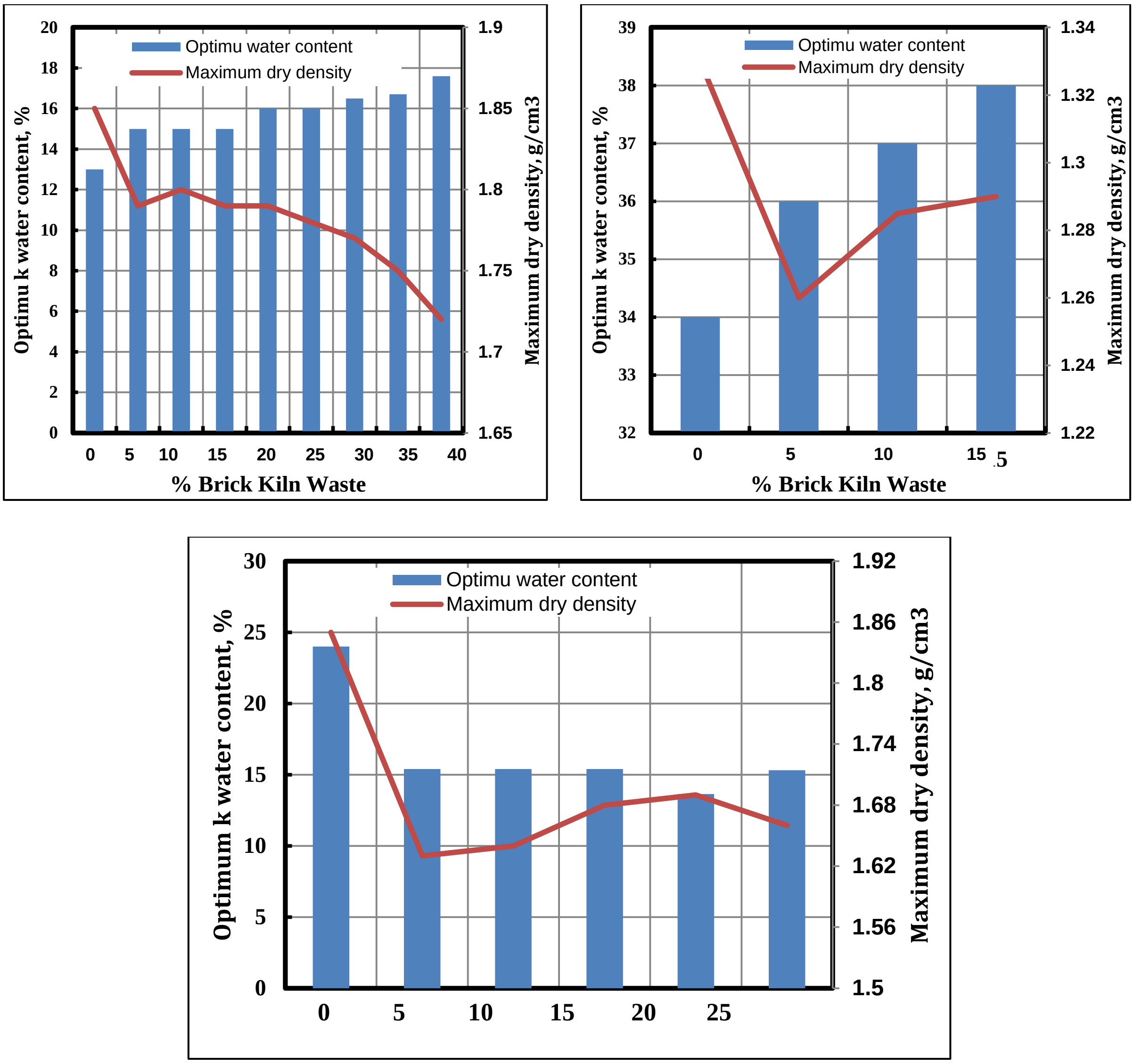

Figure 3: Effect of brick waste on compaction characteristics.

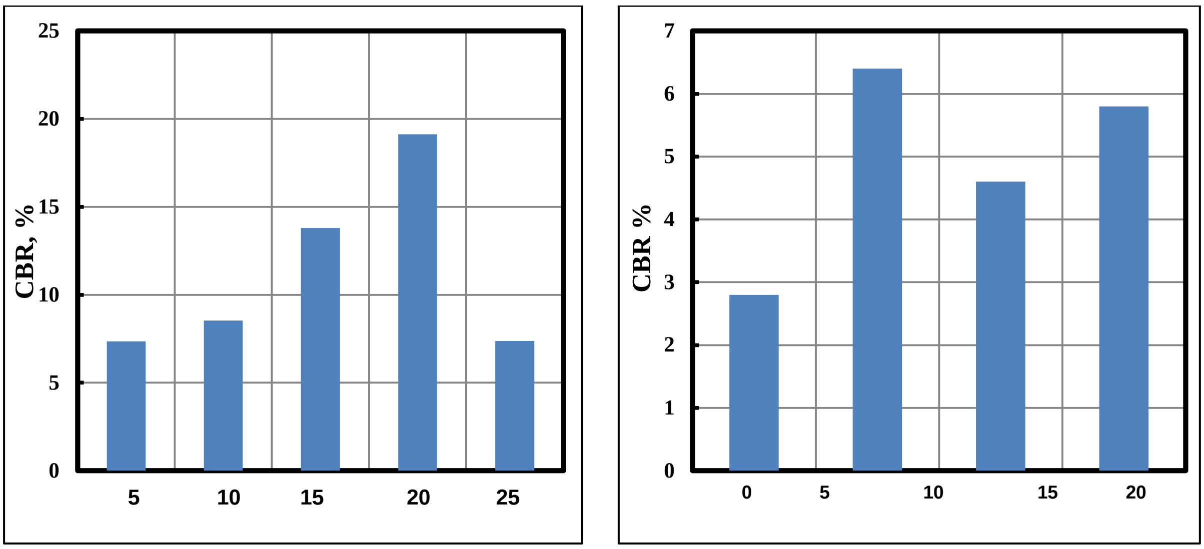

Figure 4: Effect of brick waste on CBR.

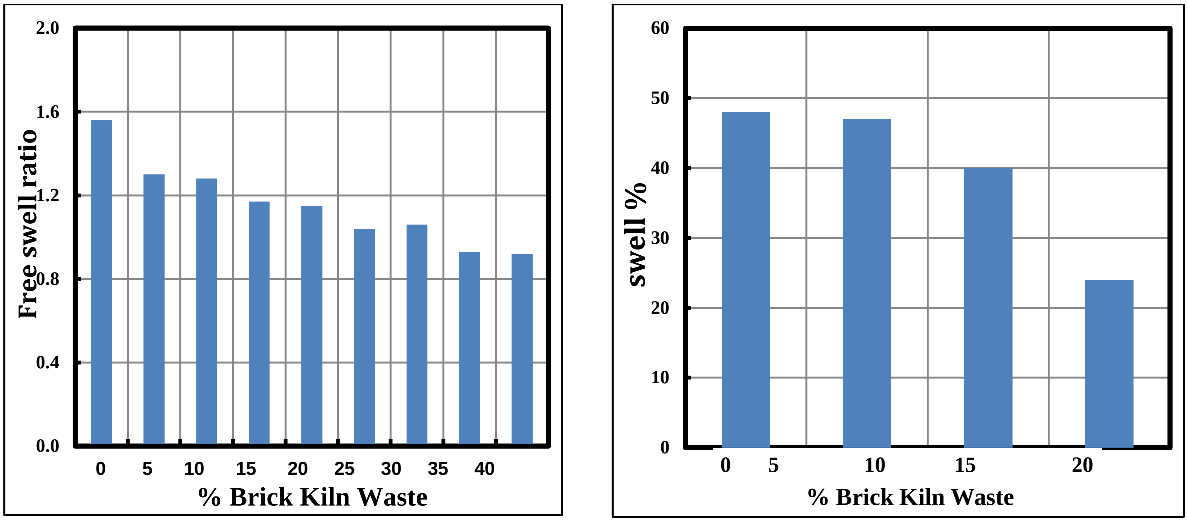

Figure 5: *Effect of brick waste on soil swelling.*

CONCLUSIONS

The applications and uses of brick waste in geotechnical and civil engineering have been reviewed in this paper. According to this review, the following was found:

- Brick waste, in different forms, has been used in many civil engineering applications, it used as aggregate materials, pavement subbase material, filter material in permeable pavements, filling material, as filler in filled pozzolanic cement, as a fine and coarse aggregates in concrete production, and as a soil stabilizer.
- Different forms of brick waste have been used in various civil engineering applications include crushed aggregates, dust form, and brick powder form. The best stabilization effect of brick waste can be obtained at the optimum content, this content, in general, varied from 40% to 50%., actually, a lower brick content is required as an optimum content when brick waste applied to soil stabilized with other material like cement, lime, or fly ash. However, the efficiency and content of brick waste are dependent on factors like soil type, initial soil condition, soil composition and its mineralogy, and etc.
- As a stabilizer for expansive soils, brick waste successes in reducing the engineering problems of these soils. It mitigates the unfavorited properties of expansive soil, it is increasing the bearing values and shear strength of expansive soils for the pavement subbase, with addition of brick waste, the cohesive soil became coarser and more suitable as a fill material (partial) for highways and buildings foundations.
- Application of brick waste in the stabilization of soil provides good results when compared to other stabilizers like lime, fly ash and cement. From an economic point of view, such application provides a cheaper alternative to conventional materials. Environmentally, using a vast amount of brick waste in soil stabilization and other civil engineering applications is lead to greener construction material and help in reducing wastes in the environment.
- Expansive soil treated with brick waste exhibited promising results in decreasing free swell index, liquid limit, plastic limit, plasticity index, soil shrinkage, and the swelling potential. The positive reaction of brick waste is due to its effect as a filler material and as a pozzolanic material. It is reacting chemically with components of soil. Although, most literature has discussed

the effect of brick waste on physical properties and soil strength, unfortunately, consolidation, permeability, and durability are comparatively less investigated.

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