Suitability of brick kiln waste as a stabilizer to clayey soils

Abdullah Saand[1], Muhammad Auchar Zardari[2*], Manthar Ali Keerio[3], Sabir Hussain Shaikh[4], and Daddan Khan Bangwar[5]

[1]Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Sindh, Pakistan

e-mail: abdullah.saand@gmail.com

Cell: 00923330231140

[2]Assistant Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Sindh, Pakistan

e-mail: muhammad.auchar@quest.edu.pk

Cell: 00923331225200

[3]Assistant Professor, Department of Civil Engineering, Quaid-e-Awam University College of Engineering, Science and Technology, Larkano, Sindh, Pakistan

e-mail: mantharali99@quest.edu.pk

Cell: 00923058414669

[4]Resident Engineer, Architecture and Engineering Services for Sindh Basic Education Program-II, Halcrow Pakistan, Pvt. Ltd, House No. C-172, Block C, Government Employees Cooperative Housing Society, Sukkur, Sindh, Pakistan

e-mail: sabir.hussain@halcrowpk.com

Cell: 00923337187140

[5]Assistant Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Sindh, Pakistan

e-mail: daddan@quest.edu.pk

Cell: 00923337016912

* Corresponding author

e-mail: muhammad.auchar@quest.edu.pk

Cell: 00923331225200

Abstract

Due to increased use of brick masonry for construction of buildings in Pakistan, huge quantities of Brick Kiln Waste (BKW) are generated which not only create disposal problems but are a hazard to the environment. In order to get rid of such problems, it is necessary to investigate suitability of the BKW as a stabilizer to the clayey soils. For this purpose, an experimental program was carried out to stabilize clayey soil with the BKW ranging from 5 to 40%. Basic geotechnical tests were performed on the clayey soil blended with the BKW. The results showed that the clayey soil became coarser and more suitable as a subgrade material with addition of the BKW. There was negligible reduction in dry density up to 7% when the BKW added was 40%. As expected, the cohesion and friction angle of the blended soils respectively decreased and increased with inclusion of the BKW. As compared to the clayey soil, the ultimate bearing capacity of the blended soil having 40% of the BKW increased by 21%. This study shows that clayey soils stabilized with the BKW could be used as a partial fill material for highway embankments and foundations of buildings.

Keywords: Clayey soil; Brick kiln waste; Stabilizer; Bearing capacity; Dry density; Cohesion; Friction angle.

1. Introduction

Presently, fired bricks are widely used for construction of buildings. Due to continuous increase in the population of Pakistan, there is more demand for houses. To meet demand for houses, bricks are manufactured on a large scale. In Pakistan, approximately 18000 kilns are in operation which fire about 45 billion bricks annually [1]. The fuel used for firing of bricks in kilns consists of: wood, agricultural by-products such as rice husk, sugarcane bagasse, old pieces of clothes etc. As a result, a huge quantity of waste consisting of ash and small pieces of bricks is generated on the sites where the kilns are located. The current practice in Pakistan is that the Brick Kiln Waste (BKW) is not disposed of properly. The BKW gradually accumulates on the sites of the kilns. The accumulated BKW may create not only disposal but environmental problems. To alleviate these problems, it is necessary to investigate whether the BKW can be used as a stabilizer for clayey soils which are considered as poor material for various civil engineering works.

Highway embankments and foundations of buildings require massive quantities of fill materials. The clayey soils may exhibit low bearing capacity, high compressibility and settlement. As a result, the pavements of roads may experience cracks and buildings may suffer from differential settlement which may reduce their service life. Under these conditions, the clayey soils may be stabilized with granular soils to achieve satisfactory performance. The use of the BKW as a partial fill material with clayey soils in highway embankments and foundations of buildings could be a better option instead of disposal which is costly.

Throughout the world, billions of tons of solid waste are generated annually. Efforts are being made to implement waste management practices to reduce environmental problems of the solid wastes [2-4]. Nowadays, solid wastes are being utilized in various civil engineering works such as: soil stabilization [5-8] and landfills [9-10]. Fly ash has been utilized as a partial fill material in highway embankments [11-14]. Rice husk ash is also used as a partial construction material in highways [15-17]. Waste ceramic dust [18], marble dust [19] and brick dust [20] have also been utilized for soil stabilization. The authors are of the view that no study has been published on suitability of BKW as a stabilizer in civil engineering construction projects. The purpose of this study is to assess the usefulness of the BKW as a partial fill material for construction of highway embankments and foundations of buildings. For this purpose, index properties, compaction, shear strength parameters, and ultimate bearing capacity of the clayey soil partially blended with the BKW are determined.

2. Materials and Methods

2.1 Materials

Clayey soil samples were excavated near Nawabshah city. The BKW was obtained from a local brick kiln in the surrounding of Nawabshah city (Fig 1). The BKW consisted of ash of rice husk and wood, and small pieces of broken bricks which were finer than the No. 4 sieve. The larger pieces of the bricks were broken and made finer than the No. 4 sieve. The BKW was blended with the clayey soil with an increment of 5% by weight. This mixing process of the BKW with clayey soil was increased up to 40%.

Place Figure 1 here.

2.2 Testing program

The particle size distribution curves of the soils were evaluated using ASTM D422 [21], liquid limit and plastic limits were determined with ASTM D4318 [22]. The soils were classified according to AASHTO classification system [23]. Moisture density relationship, and shear strength parameters of the soils were evaluated using references ASTM D1557-12 [24], and ASTM D3080/D3080M-11 [25], respectively. Free swell ratio of the soils was determined using the procedure described by Prakash and Sridharan [26].

3. Results and discussions

3.1 Liquid limit, plastic limit and plasticity index of the soils

Table 1 shows the values of plastic limit, liquid limit and plasticity index of all the soil samples. As expected, the values of the above-mentioned parameters of the blended soils decreased with the increase in content of the BKW. As compared to the clayey soil, the values of the liquid limit, plastic limit and plasticity index of the blended soil having 40%

BKW were respectively reduced by 27%, 28%, and 11%. The decrease in consistency values of the blended soils is due to increase in coarse particles of the BKW.

Place Table 1 here.

3.2 Classification

The particle size distribution curves of the clayey soil mixtures blended with various proportions of the BKW are presented in Fig 2. It can be observed that the range of particle size of clay and the BKW lies between 2 mm to 0.01 mm and 4.75 mm to 0.01 mm, respectively. For all the mixes, the soils are well graded. The original soil was classified as A-7-5 group (clayey soil) which is considered as a poor soil. The blended soil improved to A-4 (silty soil) and A-2-4 (silty or clayey gravel and sand) groups respectively, when the BKW was increased from10% to 30%, and 35% to 40%. This implies that the blended soil became coarser with increase in the BKW as compared to the clayey material. According to AASHTO classification system, the A-7-5 and A-2-4 groups represent respectively the poor and good quality subgrade soils. A-2-4 soils are appropriate material for construction of embankments. Soils belonging to A-4 group can also be used as a fill material for embankments of low height in those locations where the moisture is not expected to increase above the placement water content [see, e.g., 27].

Place Figure 2 here.

3.3 Effect of brick kiln waste on moisture-density relationship of soils

Modified Proctor compaction tests were carried out on the soil samples that contained clay, the BKW, and the blended soils. The Optimum Moisture Content (OMC) and the maximum dry density values of the blended soils were evaluated (Fig 3). The values of OMC increased, and the dry density decreased with the increase in the BKW (Table 2). This is because the BKW is a porous material which absorbed more water and thus the OMC was increased, and the dry density was reduced. The values of dry density of the clay slightly reduced from 18.5 kN/m^3 to 17.9 kN/m^3 and 17.2 kN/m^3 respectively when it was blended with 5% and 40% of the BKW. The values of the dry density of the blended soils are comparable to that of mixture of sand and gravel, and well graded sands [see, e.g., 28].

It is to be noted that the maximum reduction in value of dry density of the blended soil was 7% when the BKW added was 40%. This implies that the if the BKW is available in large volumes, it could be utilized as high as 40% with clayey soil without affecting dry density.

Place Figure 3 here.
Place Table 2 here.

3.4 Effect of brick kiln waste on shear strength parameters of the soil

Shear strength parameters (cohesion and friction angle) of the clayey soil mixed with different percentages of the BKW were determined from shear box tests. The cohesion of the blended soils decreased (Fig 4) and the friction angle was increased (Fig 5) with increase in the BKW. The cohesion and friction angle values of the blended soils were respectively decreased by 40% and increased by 38% when the BKW added was 40%. This is because the blended soils contained coarse and angular particles of the BKW.

Place Figure 4 here.
Place Figure 5 here.

3.5 Effect of the brick kiln waste on ultimate bearing capacity of clayey soil

In order to find the potential of the clayey soils stabilized with the BKW, bearing capacity of an isolated square footing of 2 m x 2 m and depth 2 m was calculated using Terzaghi's bearing capacity equation [see, e.g., 29]:

$$q_u = cNc + \gamma DNq + 0.5\gamma BN\gamma \qquad (1)$$

where q_u, c, γ, D, and B respectively are ultimate bearing capacity, cohesion, unit weight of the soil, depth of foundation, width of footing, and N_c, N_γ, N_q are Terzaghi's bearing capacity factors.

The ultimate bearing capacity of the soils blended with the BKW is presented in Fig 6. The ultimate bearing capacity of the blended soils increased with increase in the BKW. The ultimate bearing capacity of the clayey soil mixed with 40% BKW increased by 21%. The ultimate bearing capacity of the clayey soil blended with 25% of the BKW was about 430 kPa. According to International Code Council [30], the ultimate bearing capacity of sandy gravel and/or gravel is about 430 kPa. This implies that the BKW could be utilized with clayey soil as a foundation material without compromise on bearing capacity.

Place Figure 6 here.

3.6 Effect of brick kiln waste on the swelling properties of the clayey soil

The free swell ratio of the blended soils decreased with the increase in the BKW (Fig 7). According to the criteria suggested by Prakash and Sridharan [26], the degree of expansion of clayey soil was moderate. With addition of the BKW in the clayey soil up to 30%, the expansion of the blended soil became low. Finally, the degree of expansion of the blended soils became negligible when mixed with 35% to 40% of the BKW.

Place Figure 7 here.

4. Conclusions

In this study, the suitability of the Brick Kiln Waste (BKW) as a stabilizer for clayey soils is examined. Main findings of this study are summarized as under:

1. With addition of the BKW, the clayey soil became more coarse and appropriate as a partial fill material for highways and foundations of buildings.
2. The dry density of the blended soil slightly reduced by 3% and 7% respectively when the BKW added was 20% and 40%.
3. Values of cohesion and friction angle of the clayey soil were reduced and increased respectively by 40% and 39% when the BKW added was 40%.
4. In comparison to clayey soil, ultimate bearing capacity of the blended soils increased by 21% when the BKW mixed was 40%.
5. The results presented in this study suggest that the BKW could be utilized as a stabilizer in clayey soils to be used in highway embankments and foundations of buildings.

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Biography of Authors

Abdullah Saand is Professor in Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science, and Technology (QUEST), Nawabshah, Pakistan. He received PhD in Structural Engineering from University of Technology Malaysia in 2007. His research interests include: Polymer Modified Concrete, properties of construction materials, and concrete repair.

Muhammad Auchar Zardari received PhD from Lulea University of Technology, Lulea, Sweden in Soil Mechanics and Foundation Engineering in 2013. Presently, he is an Assistant Professor at the Department of Civil Engineering, QUEST Nawabshah, Pakistan. His research interests include: numerical modelling of geotechnical structures, long-term stability of embankment dams, internal erosion of dams, geotechnical properties of waterlogged soils, and soil stabilization.

Manthar Ali Keerio is Assistant Professor in Civil Engineering Department at QUCEST Larkano. He received PhD in Structural Engineering from QUEST Nawabshah in 2017. His research interests include supplementary cementing materials and self-consolidating concrete.

Sabir Hussain Shaikh has obtained Master of Civil Engineering from QUEST Nawabshah in 2015. Presently he is working as Resident Engineer in Halcrow Pakistan, Pvt. Ltd. His research interests are: Soil Stablization with solid waste materials.

Daddan Khan Bangwar is Assistant Professor in Civil Engineering Department at QUEST Nawabshah. He received PhD in Structural Engineering from QUEST Nawabshah in 2016.

His research interests include supplementary cementing materials and Polymer Modified Concrete.

Figure captions

Figure 1. A view of Brick Kiln Waste generated by a local brick manufacturing works.

Figure 2. Particle size distribution curves of soils blended with 5 to 40% Brick Kiln Waste (BKW).

Figure 3. Moisture density relationship of the soils mixed with 5 to 40% Brik Kiln Waste (BKW).

Figure 4. Effect of addition of Brick Kiln Waste on cohesion of the clayey soil.

Figure 5. Effect Brick Kiln Waste on friction angle of the clayey soil.

Figure 6. Ultimate bearing capacity of the clayey soil blended with various proportions of Brick Kiln Waste (BKW).

Figure 7. Decrease in free swell ratio of the clayey soil blended with 5 to 40% Brick Kiln Waste (BKW).

Figures

Figure 1

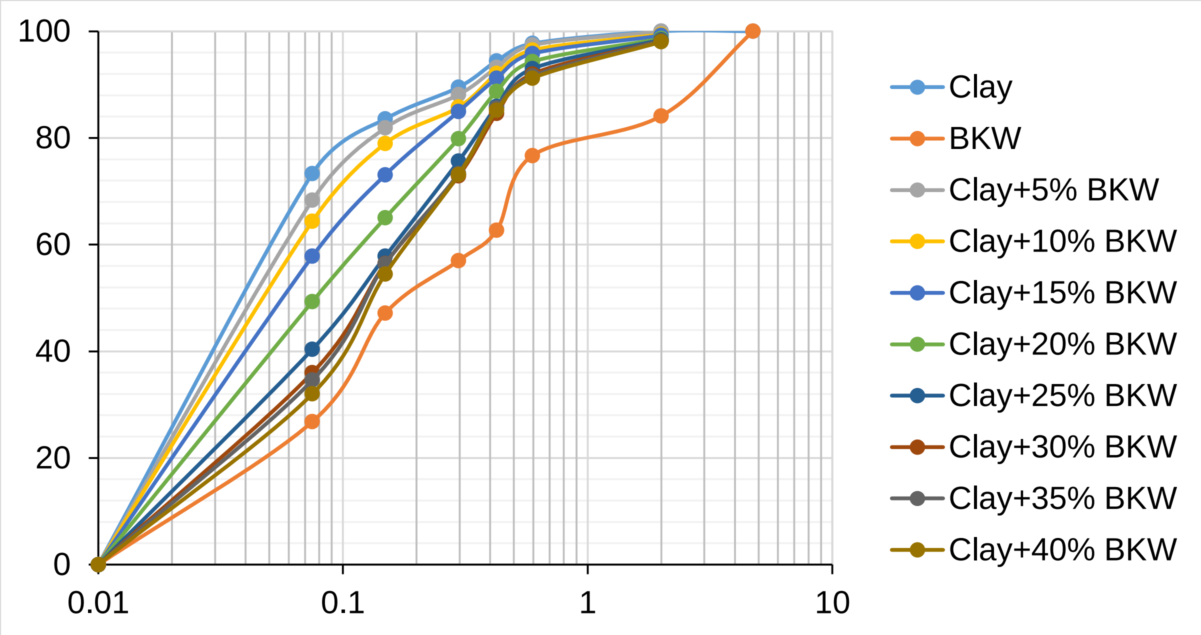


Figure 2

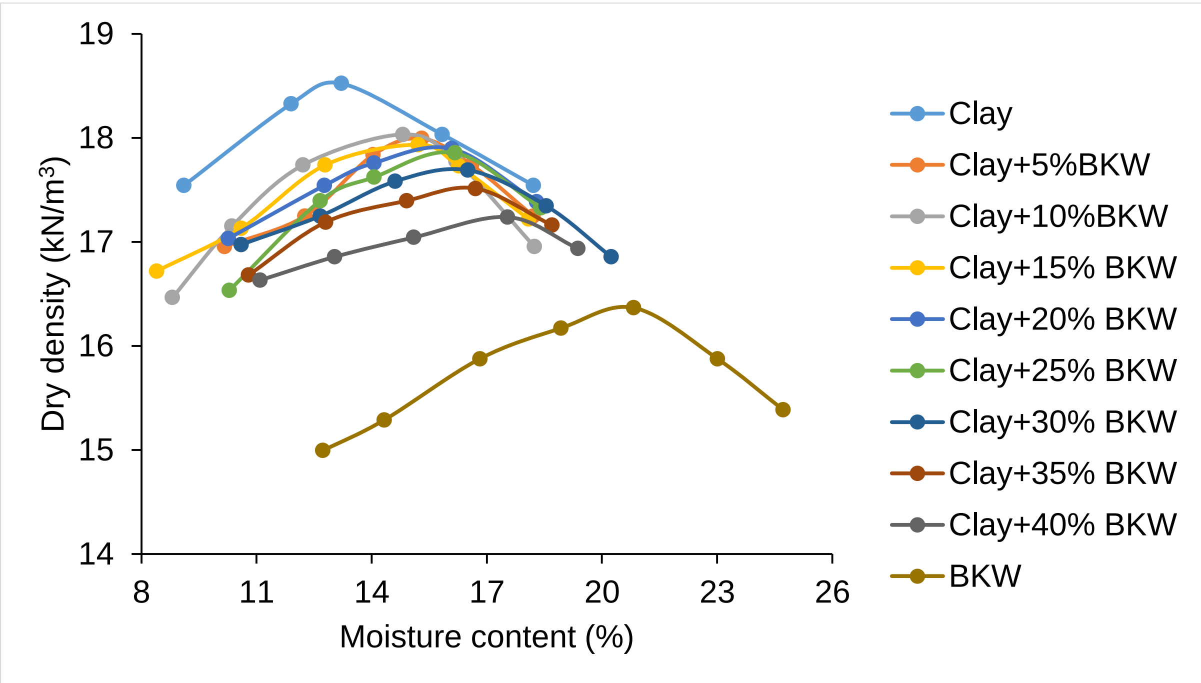


Figure 3

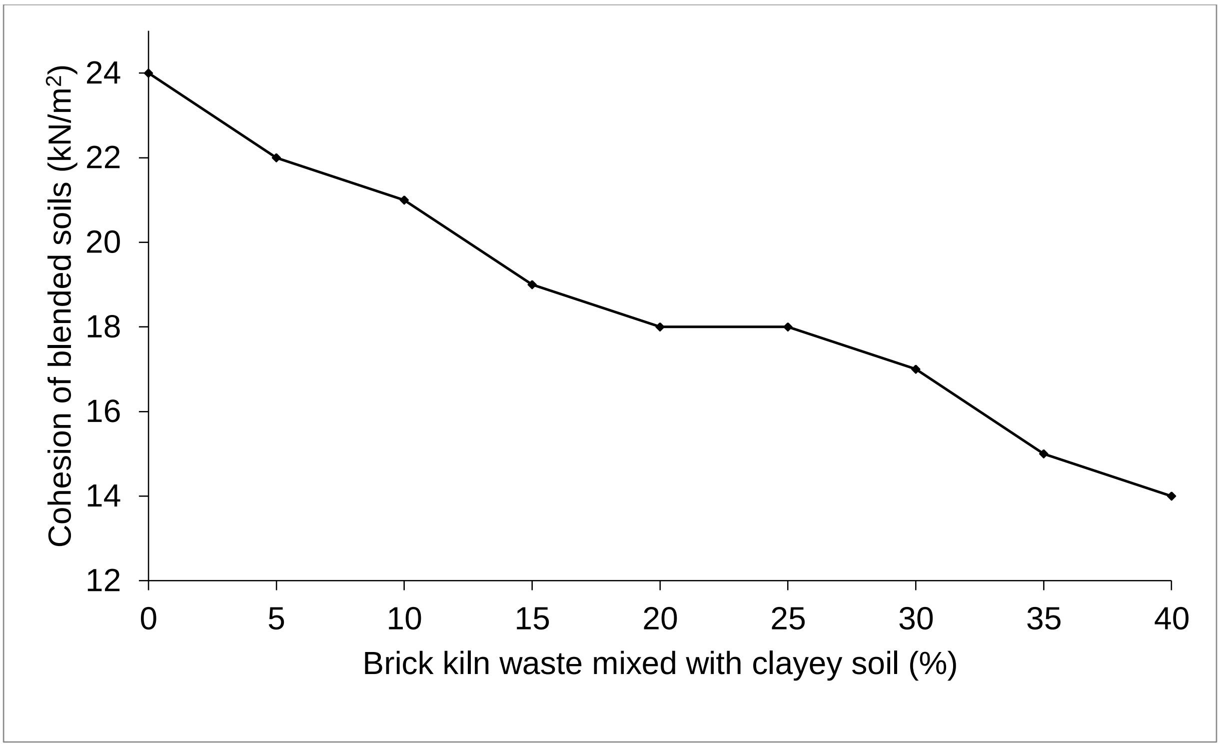
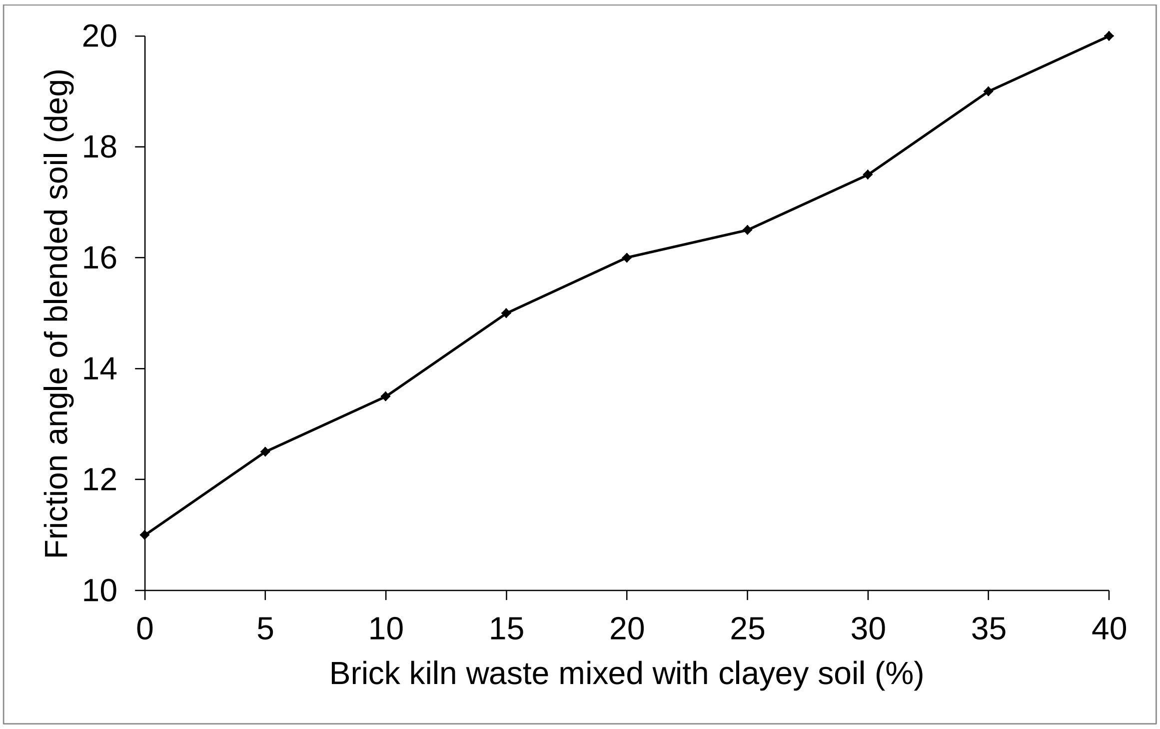

Cohesion of blended soils (kN/m²)
24
22
20
18
16
14
12
0
5
10
15
20
25
30
35
40
Brick kiln waste mixed with clayey soil (%)

Figure 4


Friction angle of blended soil (deg)
20
18
16
14
12
10
0
5
10
15
20
25
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35
40
Brick kiln waste mixed with clayey soil (%)

Figure 5

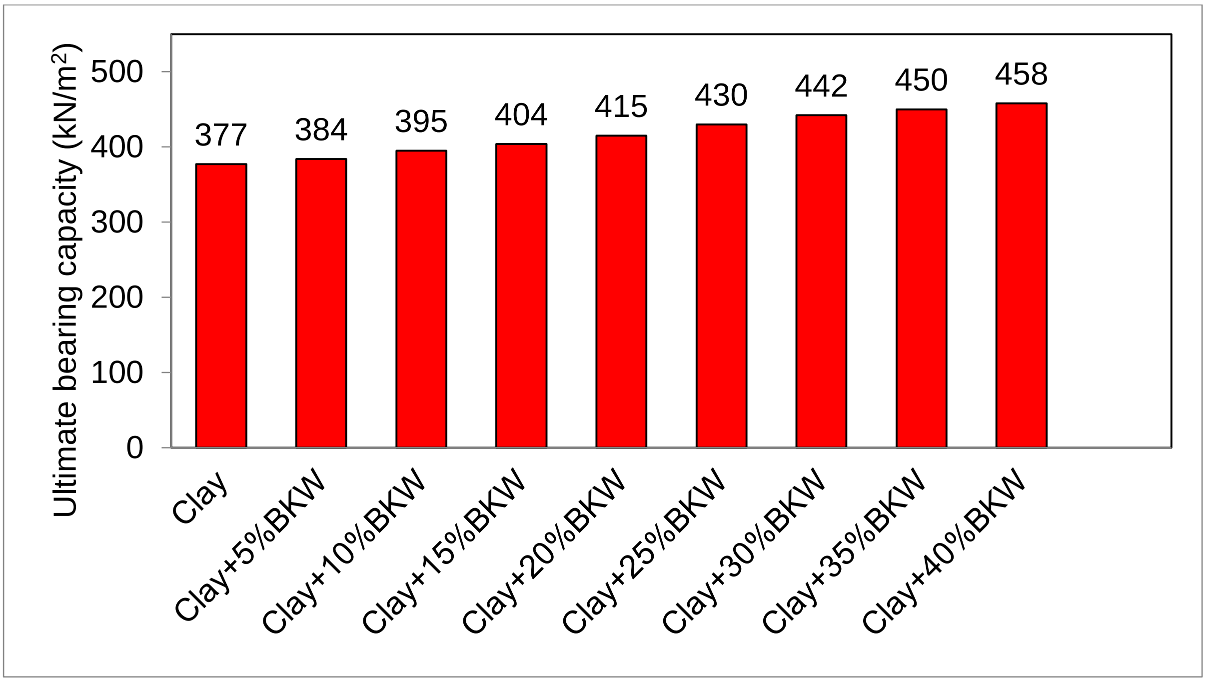

Figure 6

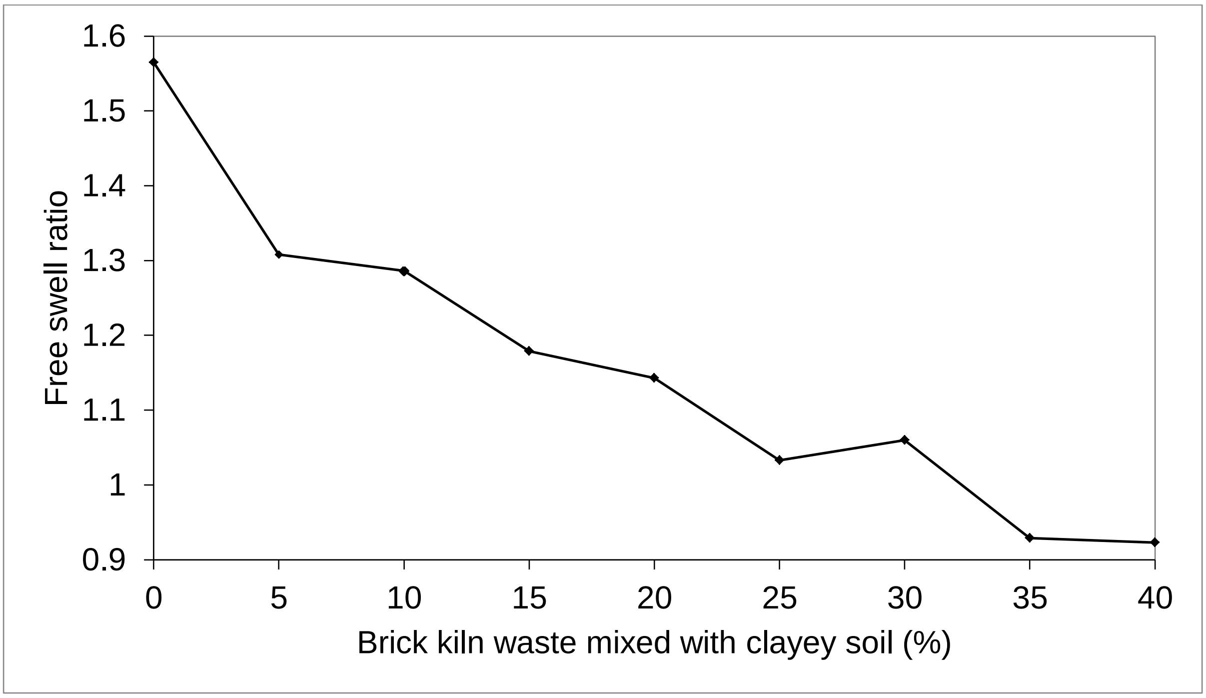

Figure 7

Table captions

Table 1. Index properties of the clayey soil blended with Brick Kiln Waste (BKW).

Table 2. Optimum moisture content and maximum dry density values of the soil mixed with various proportion of the Brick Kiln Waste (BKW).

Tables

Table 1

S. No.	Soil mixture	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	% passing from #200 sieve	AASHTO classification
1	Clay	47	35	12	73	A-7-5
2	Brick Kiln Waste (BKW)	21	19	2	26	A-2-4
3	Clay + 5% BKW	45	34	11	68	A-7-5
4	Clay + 10% BKW	44	33	11	64	A-5
5	Clay + 15% BKW	42	33	9	57	A-5
6	Clay + 20% BKW	40	30	10	49	A-5
7	Clay + 25% BKW	39	29	10	40	A-4
8	Clay + 30% BKW	38	29	9	36	A-4
9	Clay + 35% BKW	37	28	9	34	A-2-4
10	Clay + 40% BKW	34	25	9	32	A-2-4

S. No	Soil mixture	OMC (%)	Increase in OMC (%) as compared to clay	Dry density (kN/m^3)	Decrease in dry density (%) as compared to clay
1	Clay	13	-	18.5	-
2	Brick Kiln Waste (BKW)	20	-	16.4	-
3	Clay + 5% BKW	15	15	17.9	3
4	Clay + 10% BKW	15	15	18	3
5	Clay + 15% BKW	15	15	17.9	3
6	Clay + 20% BKW	16	23	17.9	3
7	Clay + 25% BKW	16	23	17.8	4
8	Clay + 30% BKW	16.5	26	17.7	4
9	Clay + 35% BKW	16.7	28	17.5	5
10	Clay + 40% BKW	17.6	35	17.2	7

Table 2