JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Development of Interlocking Compressed Earthen Bricks and its Analysis

**[1]Prof. Kedar Shivaji Redekar, [2]Pran Dagadu Kamble**.

[1]Professor, Department of Civil Engineering, D. Y. Patil Technical Campus, Talsande, Kolhapur,
[2,]UG Students, Department of Civil Engineering, D. Y. Patil Technical Campus, Talsande, Kolhapur,
Department of Civil Engineering,
[1]Shivaji University, City-Kolhapur, Country-India

**ABSTRACT**

The demand for sustainable and cost-effective construction materials has led to the exploration of innovative alternatives to conventional bricks. This project focuses on the development of Interlocking Compressed Earthen Bricks (ICEBs), a green building technology that minimizes the use of mortar, reduces construction costs, and offers better environmental performance.The process involves selecting suitable soil, stabilizing it with additives like cement or lime, and compressing the mixture using mechanical presses to achieve high strength and durability. The interlocking design enhances structural stability and simplifies the construction process.An extensive analysis was carried out to study the physical and mechanical properties of the developed ICEBs, including compressive strength, water absorption, and durability under different environmental conditions. The results demonstrate that properly engineered ICEBs can meet standard construction requirements while offering significant environmental and economic advantages.This study highlights the potential of ICEBs as a sustainable alternative for future construction practices, promoting eco-friendly development without compromising quality and performance.

## 1.INTRODUCTION

Soil is the most basic preliminary construction material. Construction with conventional method using clay bricks have some limitations. Greater water absorption, more self-weight and we use fertile soil for casting of clay bricks. The Interlocking compressed earthen bricks are unburnt, so during their production no fuel is used. This compressed earthen bricks with interlocking have many advantages and ability to adapt a wide range of architectural, economic, physical, social, and ecological factors. By altering cement content of Interlocking compressed earthen bricks and addition of fibrous material & cavities we can reduce the weight of brick. The project is focused on engineering properties such as water absorption, self-weight, etc. of the brick.

In order to attain sustainable technology in the construction sector, certain other approaches have been developed to replace the conventional building materials, which lack attention to sustainability factors, particularly those relating to economics, people, and the environment. Due to their production process, conventional bricks, in particular Fired Clay Brick (FCB), use and emit a lot of energy. Additionally, increased carbon emissions from the burning of gasoline add to the greenhouse impact. As a result, Interlocking Compressed Earth Bricks (ICEB) are created as an alternative to using bricks the way they have traditionally been used. In terms of price, lead time, and sustainable development, ICEB offers additional benefits.

### 1.1 Problem Statement

Now-a-days it is observed that traditionally used building construction units such as **Autoclaved Aerated Blocks (AAC) blocks, fly ash bricks, fire clay bricks**, etc. involve more carbon which is major contributor to the **air pollution**.

Burning of clay bricks with **carbon emission** have resulted in many climate changes which is thoroughly affecting our environment. '**Interlocking compressed earthen bricks**' can be a better alternative to tackle this problem.

### 1.2 Aim of Project

To develop 'Interlocking compressed earthen bricks (ICEB)' for minimizing cost & consumption of cement content during masonry construction.

### 1.3 Objectives of Project

1. To evaluate optimum mix proportion of different ingredients required for manufacturing of ICEB through literature survey.
2. To prepare design of mold & brick casting machine.
3. To cast ICEB using pre obtained optimum mix proportion.
4. To perform tests on prepared ICEB samples for their engineering properties.

### 1.4 Significance of the project

This initiative may be one step forward in achieving in sustainable development. ICEB (Interlocking Compressed Earthen Bricks) is a modern-day building units should be study for:
1. To reduce the Cost:
ICEB are manufactured with the use of earthen materials also due to the provision of interlocking the construction doesn't need mortar.

2. To adopt simple construction process:
ICEBs are interlocking, so they can be easily assembled by unskilled workers without the need for special tools or equipment.

3. Reduced carbon Emission:
The most important factor for preferring CEB is reduced carbon emission as compared to traditionally used bricks.

## 2.RESEARCH METHODOLOGY

### 2.1. Identification of Problem Statement
### 2.2. Literature Review
### 2.3.Soil Selection and Preparation

- **Soil Sampling**: Local soils were collected from different locations and tested for suitability based on texture, plasticity, and grain size distribution.
- **Soil Testing**: Standard geotechnical tests such as Atterberg limits, particle size analysis, and Proctor compaction test were performed to determine the ideal mix for brick production.
- **Sieving and Drying**: Soil was sieved through a 4.75 mm sieve and air-dried to remove oversized particles and excess moisture.

### 2.4. Mix Design

- **Stabilization Materials**: Cement (5–10%) was used as a stabilizer to improve strength and durability.
- **Water Content**: Optimum moisture content was determined using compaction tests to ensure workability and strength.
- **Mixing**: Soil, stabilizer, and water were thoroughly mixed manually or with a mechanical mixer to form a uniform mixture.

### 2.5 Brick Molding and Compaction

- **Molding Machine**: A manually operated or hydraulic interlocking brick press was used to shape the bricks with interlocking keys.
- **Compaction**: High pressure was applied during molding to increase the density and strength of the bricks.
- **Curing**: Bricks were cured for a minimum of 14–28 days using wet gunny bags or sprinkling water to achieve maximum strength.

### 2.6 Testing and Analysis

- **Compressive Strength Test**: Conducted using a universal testing machine to assess load-bearing capacity.
- **Water Absorption Test**: Measured to evaluate durability and resistance to moisture.
- **Thermal Conductivity Test**: Carried out to determine the insulation properties of ICEBs.
- **Dimensional Accuracy and Interlocking Efficiency**: Verified for proper fit and ease of construction without mortar.
- **Cost Analysis**: Compared with conventional fired bricks to assess affordability.

### 2.7 Final Report & Conclusion

## 3. LITERATURE REVIEW

**➢ Paper title: 1. Earth construction: Lessons from the past for future coefficient construction**
• Author: F. Pacheco Torgal
• Name of journal: Construction and Building Materials.
• Date of publication: 2005
• Findings from the paper:
1. Developing nations are typically where you will see this kind of structure.
2. The kind of binders utilized determines how inexpensive the building will be.

**➢ Paper title: 2. The use of sugarcane bagasse ash and lime to improve the durability and mechanical properties of compacted soil blocks.**
• Author: Rafael Alavéz Ramírez, Jacobo Martínez-Reyes, Pedro Montes García
• Name of journal: Construction and Building Materials 34 (2012) 296–305
• Date of Publication: 2012
• Findings from the paper:
1. The performance of the blocks improved when 10% sugarcane bagasse ash and 10% lime were added.
2. Sieved SCBA produced in commercial sugar boilers may be a potential material for stabilizing soil blocks that have been compacted

➢ **Paper title: 3. Masonry CSEB Building Models under Shake table Testing-An Experimental Study**
• Author: Lakshmi Keshav
• Name of journal: International Journal of Civil and Environmental Engineering
• Date of publication: 2006
• Findings from the paper:
1. Models constructed with earthquake-resistant bands outperformed models without the bands in terms of performance.
2. Using the bands raises the overall cost of construction by 4% to 6%.

➢ **Paper title: 4. Innovations, Applications, And Standards Of Compressed Stabilized Earth Blocks**
• Author: Parera
• Name of journal: University of Moratuwa
• Date of Publication: 2003
• Findings from the paper:
1. Certain issues that CSEB and construction faced in the past were resolved.
2. The state of building has improved thanks to new methods like rat trap bond and shell construction.

➢ **Paper title: 5. Development and performance evaluation of interlocking block masonry**
• Author: K. B. Anand, and K. Ramamurthy
• Name of journal: Journal of Architectural Engineering
• Date of publication: 2001
• Findings from the paper:
1. A potential substitute for mortar-bedded brickwork is the solid interlocking block masonry system.
2. This brick masonry showed higher efficiency in axial compression.

➢ **Paper title: 6. Characteristics study of Stabilized and Compressed Laterite Soil Bricks**
• Author: Shanmuka K. N., Manjunath K., Prahallada M.C.
• Name of journal: Infra construction & equipment magazine
• Date of publication: 2022
• Findings from the paper:
1. Compressive strength of stabilized and compressed laterite soil bricks are nearly double.
2. Stabilized and compressed laterite soil bricks showed water absorption less than 20%.

➢ **Paper title: 7. Compressed Stabilized Earth Blocks by using Lime.**
• Author: Abhijeet D. Patil, Dr. A. C. Attar
• Name of journal: International Journal of Engineering Research & Technology.
• Date of Publication: 2015
• Findings from the paper:
1. By blending stone dust in to soil decreased the brick density and increased the compressive strength.
2. The brick density increases with increase in lime content.

➢ **Paper title: 8 Lime stabilization for compressed stabilized earth blocks with reduced clay and silt.**
• Author S.N. Malkanthi, N. Balthazaara, A.A.D.A.J. Perera
• Name of journal: Case Studies in Construction Materials12 (2020) e00326
• Date of Publication: 2019
• Findings from the paper:
1. Blocks stabilized with 10% lime can be used for single-story building units.
2. In case of soil blocks containing low mix proportions of clay and silt, the combination of cement and lime is more suitable than lime or cement alone.

## 4.INGREDIENTS FOR ICEB

### 4.1. Local soil

• Used local soil (Talsande & Chavre ) for casting of bricks.
• From the various tests performed, the soil is of good quality having mix graded Particle size distribution, Optimum moisture content, good cohesion and internal friction.

**Fig 5.1 Soil sample**

**4.2. Lime (CaO)**

• Lime is as an excellent soil stabilizing materials for highly active soils which undergo through frequent expansion and shrinkage.

• Lime acts immediately and improves engineering properties of soil.

**Fig 5.2.**

**4.3. Sugarcane Bagasse ash ($SiO_2$)**

• As silica present in bagasse ash - It reduces water permeability of soil.

• Acts as weight reducing agent.

**Fig 5.3. Sugarcane bagasse ash**

**4.4. Molasses [**Sucrose (29% of total carbohydrates), Glucose (12%) and Fructose (13%)**]**

• It is biodegradable and does not introduce harmful chemicals or pollutants into the environment.

• As it is sticky in nature it also acts a binding agent and help in increasing the flexural strength of ICEB.

• Molasses has a high viscosity, Molasses has hygroscopic properties, it helps prevent rapid drying and shrinkage of the bricks.

**Fig. 5.4. Molasses sample**

**5. TESTS PERFORMED ON INGREDIENTS**

**5.1. Sieve Analysis of Soil**

**Aim:** To determine the grain size distribution by dry sieve method for the soil sample.

**Fig 5.1. Sieving machine**

**Observation table:**

**Table 5.1. Observation table of sieve analysis**

| Sr. no. | IS sieve | Weight retained (gm) | %Weight retained | Cumulative % retained | Cumulative % finer |
|---|---|---|---|---|---|
| 1 | 4.75 mm | 40.3 | 4.03 | 4.03 | 95.97 |
| 2 | 2.36 mm | 205 | 20.5 | 24.53 | 75.47 |
| 3 | 1.18 mm | 273.3 | 27.33 | 51.86 | 48.14 |
| 4 | 600 µ | 268.5 | 26.85 | 78.71 | 21.29 |
| 5 | 300 µ | 114 | 11.4 | 90.11 | 8.89 |
| 6 | 150 µ | 45.8 | 4.58 | 94.69 | 5.31 |
| 7 | 75 µ | 20 | 2 | 96.69 | 3.31 |
| 8 | Pan | 33 | 3.3 | 99.99 | 0.01 |

**Result:** The soil sample is well graded soil.

**5.2 Determination of Liquid limit by Casagrande's Apparatus**

**Fig 5.2. Casagrande's Apparatus**

**Observation table:**

**Table 5.2. Observation table of Casagrande's apparatus**

| Sr. no. | Samples | 1 | 2 | 3 |
|---|---|---|---|---|
| 1 | Number of blows | 9 | 53 | 155 |
| 2 | Mass of container = M1 (gm) | 12.7 | 16.9 | 13.1 |
| 3 | Mass of container + wet soil = M2 (gm) | 37.7 | 41.9 | 38.1 |
| 4 | Mass of container + dry soil = M3 (gm) | 29.3 | 33.7 | 30.4 |
| 5 | Mass of water = M2- M3 | 8.4 | 8.2 | 7.7 |
| 6 | Mass of oven dry soil = M3 – M1 | 16.6 | 16.8 | 17.3 |
| 7 | Water content (%) W = (M2-M3) / (M3 – M1) * 100 | 50.60 | 48.80 | 44.50 |

**Result:** The liquid limit of soil sample from the graph = 49%

### 5.3. Specific Gravity test

**Aim:** To determine the specific gravity of the soil sample using Pycnometer.

**Fig 5.3. Pycnometer**

**Observations:**

1) Mass of soil = 300 gm

2) Mass of empty Pycnometer = M1 = 589.4 gm

3) Mass of Pycnometer + Soil = M2 = 889.4 gm

4) Mass of Pycnometer + Soil + Distilled water = M3 =1723 gm

5) Mass of Pycnometer + Distilled water = M4 = 1542.5 gm

**Result:**

• Specific gravity (G) = (M1 -M2) / (M4 -M1) – (M3 – M2)

= (889.4 – 589.4) / (1542.5 – 589.4) – (1723 – 889.4)
= 2.51

• Specific gravity of soil grains of given soil sample is found to be 2.51.

### 5.4. Determination of Water content

**Aim:** To determine the natural water content of a soil sample in laboratory by Oven drying method.

**Fig 6.4. Oven**

**Observations:**

1) Mass of container = M1 = 12.7 gm

2) Mass of container + wet soil = M2 = 37.7 gm

3) Mass of container + dry soil = M3 = 29.3 gm

**Result:**

• Water content = w = (M2-M3) / (M3-M1) ×100
= (37.7 – 29.3) / (29.3 – 12.7) ×100
= 50.60 %

• The average water content of the sample is 50.60%.

**5.5. Determination of Plastic limit**

**Fig 6.5. Plastic limit soil sampl**

**Observation table:**

| | | |
|---|---|---|
| **1** | **Mass of container M1 (gm)** | **12.2** |
| **2** | **Mass of container + wet soil = M2 (gm)** | **25** |
| **3** | **Mass of container + dry soil = M3 (gm)** | **20** |
| **4** | **Mass of water = M2- M3** | **5** |
| **5** | **Mass of oven dry soil = M3 – M1** | **7.8** |
| **6** | **Water content**<br>**W = (M2-M3) / (M3 – M1) ×100** | **62.5** |

**Result:**

1. The Plastic limit of soil sample from the graph = 62.5 %

2. From Casagrande's plasticity chart, soil can be classified as Inorganic clays of high Plasticity

**6. EVALUATE OPTIMUM MIX PROPORTION OF DIFFERENT INGREDIENTS REQUIRED FOR MANUFACTURING OF ICEB THROUGH LITERATURE SURVEY.**

50 Literature papers were studied from that,

1. **Soil Composition:** A key component in the development of ICEB is the nature of the soil. Good workability and strength are provided by the mixture of 70–80% sand, 30–20% silt, and 30–20% clay.

2. **Stabilizers:** Cement, lime, or fly ash are common stabilizers applied to ICEBs to increase their strength and longevity. Depending on the particular soil type and the needed level of strength. Typically, between 5 and 10% of the soil's weight.

3. **Additives:** To improve the binding capabilities of ICEBs, several additives can be added in addition to stabilizers. Depending on the targeted qualities and their particular consequences, the additive percentage varies.

**Local soil (75% ± 5%)**
**Lime (8% ± 2%)**

**Bagasse ash (10% ± 2%)**
**Molasses (7% )**

**7. PERFORMING TESTS ON PREPARED ICEB SAMPLES FOR THEIR ENGG. PROPERTIES**

**7.1 Compression Test-**

| Sample s | Proportion in % | | | | Weight (Kg) | Carried Load (KN) | | | Compressive strength (N/mm2) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Soi l | SC BA | Lim e | Mol asse | | 7d | 14d | 28d | 7d | 14d | 28d |
| Sample 1 | 70 | 10 | 15 | 5 | 6.816 | 7.56 | 7.98 | 8.28 | 0.27 | 0.36 | 0.42 |
| Sample 2 | 70 | 15 | 10 | 5 | 6.381 | 6.10 | 6.76 | 7.13 | 0.24 | 0.31 | 0.36 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample 3 | 70 | 12 | 10 | 8 | 6.543 | 6.45 | 7.36 | 7.86 | 0.29 | 0.35 | 0.39 |
| Sample 4 | 75 | 8 | 12 | 5 | 6.908 | 5.69 | 5.94 | 6.94 | 0.19 | 0.24 | 0.25 |
| Sample 5 | 75 | 10 | 8 | 7 | 6.856 | 5.36 | 6.34 | 6.65 | 0.14 | 0.19 | 0.21 |

### 7.2 Water Absorption Test-

| Sample s | Proportion in % | | | | Dry Weight(W1) (Kg) | Wet Weight(W2) (Kg) | Water absorption $\frac{W2-W1}{W1}\times 100$ |
|---|---|---|---|---|---|---|---|
| | Soi l | SC BA | Lim e | Mol asse | | | |
| Sample 1 | 70 | 10 | 15 | 5 | 6.816 | 8.56 | 21.67 |
| Sample 2 | 70 | 15 | 10 | 5 | 6.381 | 8.10 | 24.58 |
| Sample 3 | 70 | 12 | 10 | 8 | 6.543 | 8.27 | 24.78 |
| Sample 4 | 75 | 8 | 12 | 5 | 6.908 | 8.76 | 25.85 |
| Sample 5 | 75 | 10 | 8 | 7 | 6.856 | 8.67 | 24.75 |


## 8. COST COMPARATIVE ANALYSIS OF ICEB AND RED CLAY BRICKS

**Table 8.1. Cost comparative analysis for ICEB & Clay Brick Masonry for 1 m3 [1:4]**

| S. No. | Parameters | ICEB | Clay Red Bricks |
|---|---|---|---|
| 1 | Dimensions | 300mmx 150mm x 100mm | 200mmx 100mm x 100mm |
| 2 | No. of bricks / blocks | 223 | 500 |
| 3 | Mortar Quantity | Minimal or no need | 0.2766 $m^3$ |
| 4 | No. of bags of cement | 0.7 | 1.65 |

| | | | |
|---|---|---|---|
| 5 | Quantity of Sand | 0.0038$m^3$ | 0.221 $m^3$ |
| 6 | Quantity of Water | 15 Liters | 31 Liters |
| 7 | Rate Analysis | 4965.00 Rs. / $m^2$Including steel rebars (As per Nurul Malahayati et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 352 012041) | 5252.00 Rs. / $m^2$ (As per MP PWD SOR building work 2014 clause no.6.3) |

**Table 8.2. Cost comparison for plasterwork for ICEB and Clay Brick for 1 m3[1:4]**

| S. No. | Parameters | ICEB | Clay Red Bricks |
|---|---|---|---|
| 1. | The volume of mortar for plaster | 1.0 $m^3$ | 1.8 $m^3$ |
| 2. | The volume of mortar by 25% for wastage and frog filling | 1.25 $m^3$ | 2.25 $m^3$ |
| 3. | Quantity of cement | 0.25 $m^3$ | 0.45 $m^3$ |
| 4. | No. of bags of cement | 7.5 | 13.5 |
| 5. | Quantity of Sand | 1.0 $m^3$ | 1.8 $m^3$ |
| 6. | Quantity of Water | 131.25 Liters | 236.25 Liters |
| 7. | Rate Analysis | 91.10.00 Rs./ $m^2$ (Compa- red with AAC blocks plaster) | 171.00 Rs./ $m^2$ (As per MP PWD SOR building work 2014 clause no.13.6) |

**9.LIMITATIONS OF ICEB**

**1.Can sustain only smaller loads.**
•Due to weight reduction the bricks cannot sustain greater vertical and wind loads.
•They are suitably designed and used for framed structures.

**2.Less resistant to extreme weather**
•Due to lack of burning, they are not much resistance to extreme weather.

**3.Mold design is very complicated**
•The interlocking provided in the brick makes the design of mold very difficult.
•The curves present in the mold which are very necessary for interlockingare hectic to prepare.

**10.CONCLUSION**
The analysis conducted on the ingredients required for manufacturing of Interlocking Compressed Earthen Bricks from the literature survey and yielded important findings. The optimum mix proportion achieved is mentioned below.

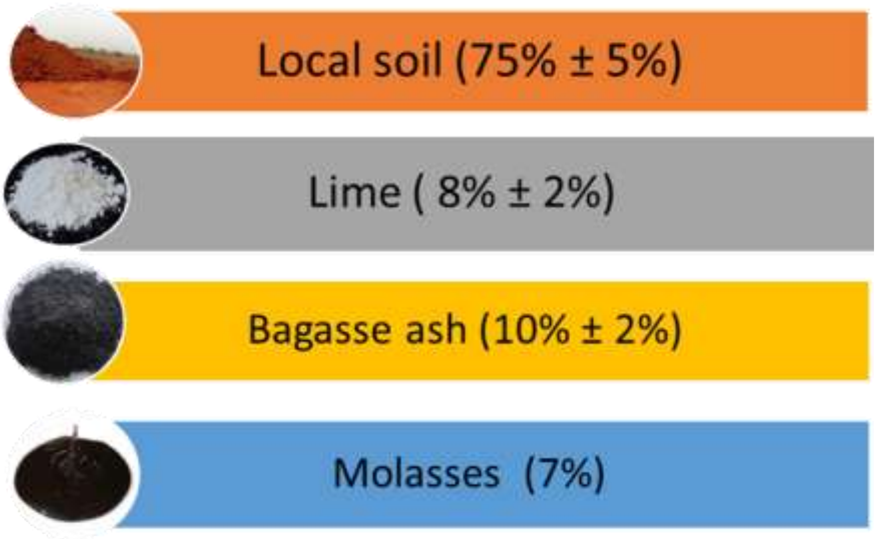


**Fig 11.1 Ingredients of ICEB**

1. Locally available soil tested for gradation, liquid limit, specific gravity, water content, and plastic limit that assisted in determining the best type of soil for ICEB manufacture.

- The addition of sugarcane bagasse ash in lime significantly improved the compressive strength and durability properties of ICEB.
- molasses has high viscosity and hygroscopic property which helped to bind and prevent shrinkage of bricks
- The design of brick was such a way that the holes provided should help in interlocking two bricks and also help to reduce the self-weight of the brick.

2. Based on the market survey and quotations received the manual brick compression machine was prepared having mechanism for smooth removal of compressed brick.
3. A number of brick samples were casted based on pre-obtained mix proportion for trial-and-error method.
4. Tests such as Compression, Water absorption, Effloresces performed on prepared brick samples for their Engineering properties

**11.REFERENCES**

1. Abhijeet D. Patil, Dr. A. C. Attar, " Compressed Stabilized Earth Blocks by using Lime", International Journal of Engineering Research & Technology, 01-09-2015.
2. F. PachecoTorgal. "Earth construction: Lessons from the past for future coefficient construction", Construction and Building Materials, 2005.
3. K. B. Anand, and K. Ramamurthy, "Development and performance evaluation of interlocking block masonry." Journal of Architectural Engineering, ASCE, Jun- 2001.
4. Lakshmi Keshav. "Masonry CSEB Building Models under Shake table Testing- An Experimental Study", International Journal of Civil and Environmental Engineering, 2006.
5. Parera. "Innovations, Applications, And Standards Of Compressed Stabilized Earth Blocks", University of Moratuwa, 2003.
6. Rafael Alavéz-Ramírez, Jacobo Martínez-Reyes, Pedro Montes-García. "The use of sugarcane bagasse ash and lime to improve the durability and mechanical properties of compacted soil blocks." Construction and Building Materials 34 (2012) 296–305, 04-04-2012.
7. Shanmuka K. N., Manjunath K., Prahallada M.C. " Characteristics study of Stabilized and Compressed Laterite Soil Bricks", Infra construction & equipment magazine, 09-08-2022.
8. Shwetha Prasanna, Swaroopa Sail, Rhea Patil, Maryann De Souza, Anushuka Prasad, "Strength analysis of soil blocks admixed with sugarcane bagasse ash", Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 04- 05-2021.
9. S.N. Malkanthi, N. Balthazaara, A.A.D.A.J. Perera, "Lime stabilization for compressed stabilized earth blocks with reduced clay and silt", Case Studies in Construction Materials12 (2020) e00326, 10-12-2019.
10. S. Srikanth Reddy, A. C. S. V. Prasad, N. Vamsi Krishna, "Lime-Stabilized Black Cotton Soil and Brick Powder Mixture as Subbase Material", Advances in Civil Engineering Volume 2018, 19-03-2018.