Chapter 5

Application Potential of Stabilized Red Mud

5.1 General

A waste material can only be used as building and construction material when the end product satisfies strength criteria, durability and leachate (leaching of harmful elements) characteristics. From Chapter 3, it is seen that stabilized red mud has good strength such as unconfined compressive strength($460 \leq q_u \leq 4350$ kPa), split tensile strength ($60 \leq q_u \leq 750$ kPa), satisfactory durability (loss in mass ≤ 30 %) and having leaching of harmful metals in within permissible limits for the range of studies ($3 \leq L \leq 11$ % , $13 \leq \gamma_d \leq 15.5$ kN/m^3, $26 \leq t \leq 60$ $days$ and $13 \leq w \leq 30$ %). After fulfillment of these criteria, the stabilized red mud may be used in different civil engineering applications such as pavement materials, unfired bricks etc.

5.2 Pavement Materials

U.S Army Corp of Engineers manual provides guidance for the design and improvement of the structural quality and workability of soils used for base-courses, sub-base courses and sub-grades for pavements construction [246]. It suggests that the minimum unconfined compressive strengths of 28 days cured lime stabilized soils should be 1380 kPa and 3450 kPa (rigid pavement) and 1725 kPa and 5170 kPa (flexible pavement) for sub-base or sub-grade and base- course layers respectively. Different codification for design criteria have been used for the representation purpose and are shown in Table 5.1 whereas, the detailed of red mud-lime mix suitable for pavement layers are summarized in Table 5.2 .

TABLE 5.1: Minimum unconfined compressive strength (q_u) criteria for lime stabilized soil in pavement layers

Pavement Type	Flexible (F)		Rigid (R)	
Pavement Layers	Sub-base course or sub-grade	Base Course	Sub-base course or sub-grade	Base Course
Minimum q_u (kPa)	1725	5170	1380	3450
Suitability	B	D	A	C

A close examination of Table 5.2 reveal that stabilized red mud can be used as pavement layers.

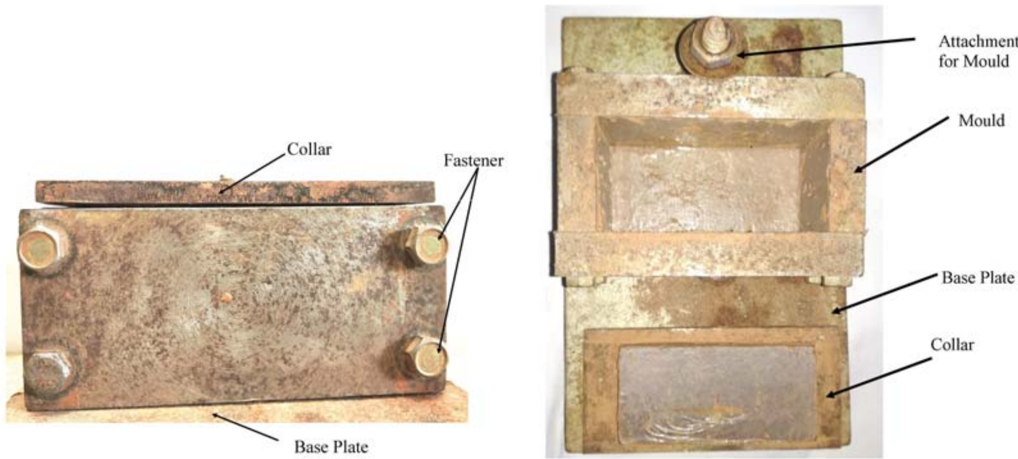
5.3 Unfired Bricks

Since, the unconfined compressive strength of some of the mix of stabilized red mud is more than 3500 kPa, these mixes have the potential to be used as unfired bricks. Thus, scaled bricks of size ($100 \times 50 \times 50$ mm) was prepared in accordance with IS 12894:2002 [247]. The mold (steel) used to prepare bricks from red mud is shown in Fig. 5.1. It was fabricated in our institute workshop. For preparing mix for brick,

TABLE 5.2: Red mud-lime mix suitable for pavement layers

Molding moisture (w) %	Curing time (t) days	Dry density (γ_d) kN/m^3	Lime content (L) (%)				
			3	5	7	9	11
26	7	13	×	×	×	×	×
		14	×	×	×	×	×
		15	×	×	A	A	A
		15.5	×	A	AB	AB	AB
	28	13	×	×	×	×	×
		14	×	×	×	A	A
		15	×	A	A	AB	AB
		15.5	A	AB	AB	AB	AB
	60	13	×	×	A	A	AB
		14	A	AB	AB	AB	AB
		15	A	AB	AB	AB	AB
		15.5	AB	AB	AB	ABC	ABC
28	7	13	×	×	×	×	×
		14	×	×	×	×	×
		15	×	×	A	AB	AB
		15.5	×	A	AB	AB	AB
	28	13	×	×	×	×	×
		14	×	×	A	AB	AB
		15	×	A	AB	AB	AB
		15.5	A	AB	AB	AB	ABC
	60	13	×	×	AB	AB	AB
		14	A	AB	AB	AB	AB
		15	AB	AB	AB	AB	AB
		15.5	AB	AB	ABC	ABC	ABC
30	7	13	×	×	×	×	×
		14	×	×	×	A	×
		15	×	×	A	AB	AB
		15.5	×	A	AB	AB	AB
	28	13	×	×	×	×	×
		14	×	×	A	A	AB
		15	×	A	AB	AB	AB
		15.5	A	AB	AB	AB	ABC
	60	13	×	×	A	AB	AB
		14	×	AB	AB	AB	AB
		15	AB	AB	AB	AB	AB
		15.5	AB	AB	ABC	ABC	ABC

Note : × = Not suitable for any pavement layers



(a) (b)

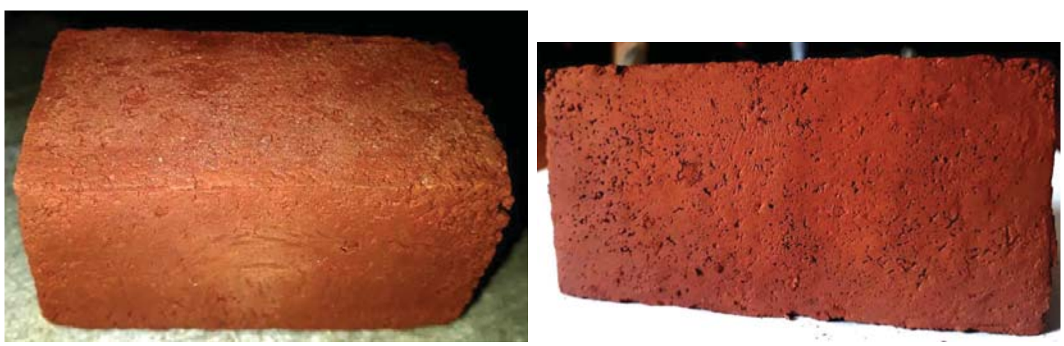
FIGURE 5.1: Fabricated brick mould along with assembly (a) front and(b) top view

the required amount of red mud and lime were mixed in a dry state to a uniform consistency and water was then added while continuing the mixing process until a uniform, homogeneous mixture was obtained. After mixing, it was transferred in the mold and compacted using hydraulic press to achieve the correct dimension. After the molding process, the sample was extracted from the mold, wrapped in an airtight polythene bag and kept in a desiccator to cure for desired curing period at room temperature ($23 \pm 3\,^{\circ}$C) while maintaining the relative humidity of more than 95%. After the molding and curing processes, the sample was tested in an automatic load compression device of 50 kN capacity with a proving ring of 10 kN capacity. The results of various mix of red mud -lime used for preparation of unfired bricks are shown in Table 5.3. Photograph of prepared brick, before and after testing are shown in Figs.5.2 and 5.3 respectively.

From Fig.5.3, multiple cracks can be seen which also indicate brittle failure of stabilized red mud bricks. The brittle behavior of bricks appears due to addition

TABLE 5.3: Mix compositions using for preparation of unfired brick

Sr. No.	Moisture content (w) %	Curing time (t) days	Dry density (γ_d) kN/m^3	Lime content (L) %	Average Compressive Strength (kN/m^3)	Water absorption (%)
1	26	28	15.5	11	3408.25	19.05
2	26	60	15.5	7	3755.18	17.89
3	26	60	15.5	9	3924.15	15.68
4	26	60	15	11	3398.68	18.78
5	26	60	15.5	11	4075.58	13.81
6	28	28	15.5	11	3789.03	18.85
7	28	60	15.5	7	3645.48	17.94
8	28	60	15.5	9	3756.24	18.58
9	28	60	15	11	3623.08	17.90
10	28	60	15.5	11	4436.29	11.85
11	30	28	15.5	11	3845.72	17.87
12	30	60	15.5	7	4048.91	14.09
13	30	60	15.5	9	4124.19	12.68
14	30	60	15	11	4621.78	11.35
15	30	60	15.5	11	4989.27	9.82



(a) (b)

FIGURE 5.2: Prepared brick (a) top and(b) front view

of lime which is also reported by various researchers [43, 248]. Further, it is also seen that the stabilized red mud unfired bricks fulfill the requirement of compressive strength (>3.5 MPa) and water absorption(<20 %) as per IS 12894:2002 [247]. Thus, the brick can be used in low cost housing which will save not only the conventional constructional materials but also solve the storage problem. This will also reduce the chance of contamination of surface and subsurface water bodies.

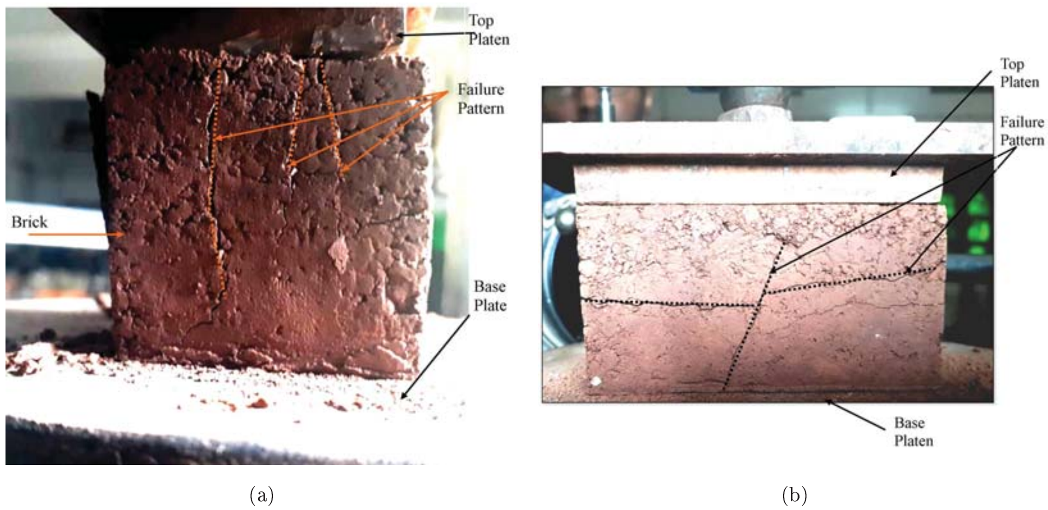


FIGURE 5.3: Failed brick (a) side and(b) front view

5.4 Demonstration of Proposed Predictive Equations

In the previous chapters, different types of predictive equations are proposed to reach the target strength of stabilized red mud. An example detailing the step-by-step procedure for the calculation of quantities for a particular variable present below. For example, a practicing civil engineer wishes to construct a pavement with stabilized red mud. So, the basic design criteria that need to be fulfilled for any stabilized material are :

- The minimum unconfined compressive strength should be 1380 and 1725 kPa for sub-grade or sub-base course in rigid and flexible pavement respectively.
- Should be satisfactorily durable.
- Leaching of harmful element in their permissible limits.

In view of the above, one can take a target value of 1750 kPa which need to be reached by different combinations of various factors such as ($3 \leq L \leq 11$ % ,

$13 \leq \gamma_d \leq 15.5\ kN/m^3$, $26 \leq t \leq 60\ days$ and $13 \leq w \leq 30$ %). The target strength can be achieved in different ways as shown in Table 5.4.

TABLE 5.4: Selection of stabilized red mud mix for use in pavement

Option	w	t	L	γ_d	Purpose
A	26	7	8.25	15.5	Short curing & less water consumption
B	26	7	11	14.9	
C	26	28	5	15.1	Intermediate curing & less water consumption
D	26	28	11	13.75	
E	26	28	8.5	14	
F	26	60	6.2	14	Intermediate lime content & less water consumption
G	26	60	4	14.78	
H	28	28	10	14	Intermediate dry density & intermediate water consumption
I	28	60	6.6	140	
J	30	7	11	15.25	High dry density & high water consumption
K	30	28	4.4	15.5	

From Table 5.4, it is seen that different combination of parameters can be used to reach the target value and the best option can be chosen depending upon the available situation. For example, if a project needs to be completed in short duration and construction site has less availability of water, then in that situation the engineer can prefer option A or B. Similarly, if the contractor has latest construction equipment and the site has no water scarcity, then one can choose option J or K. Similarly, other proposed predictive equations can also be used for appropriate selections of parameters to reach the target values (q_u).

5.5 Construction Sequence and Quality Control

Practical engineers have many options to achieve target strength according to requirements, application modes, site conditions, equipment, materials and manpower availability. Once the proportion of the mixture is fixed, it is applied sequentially in the field. The flowchart showing the complete details of construction sequences and quality control is illustrated in Fig.5.4. It primarily consist of scarifying or

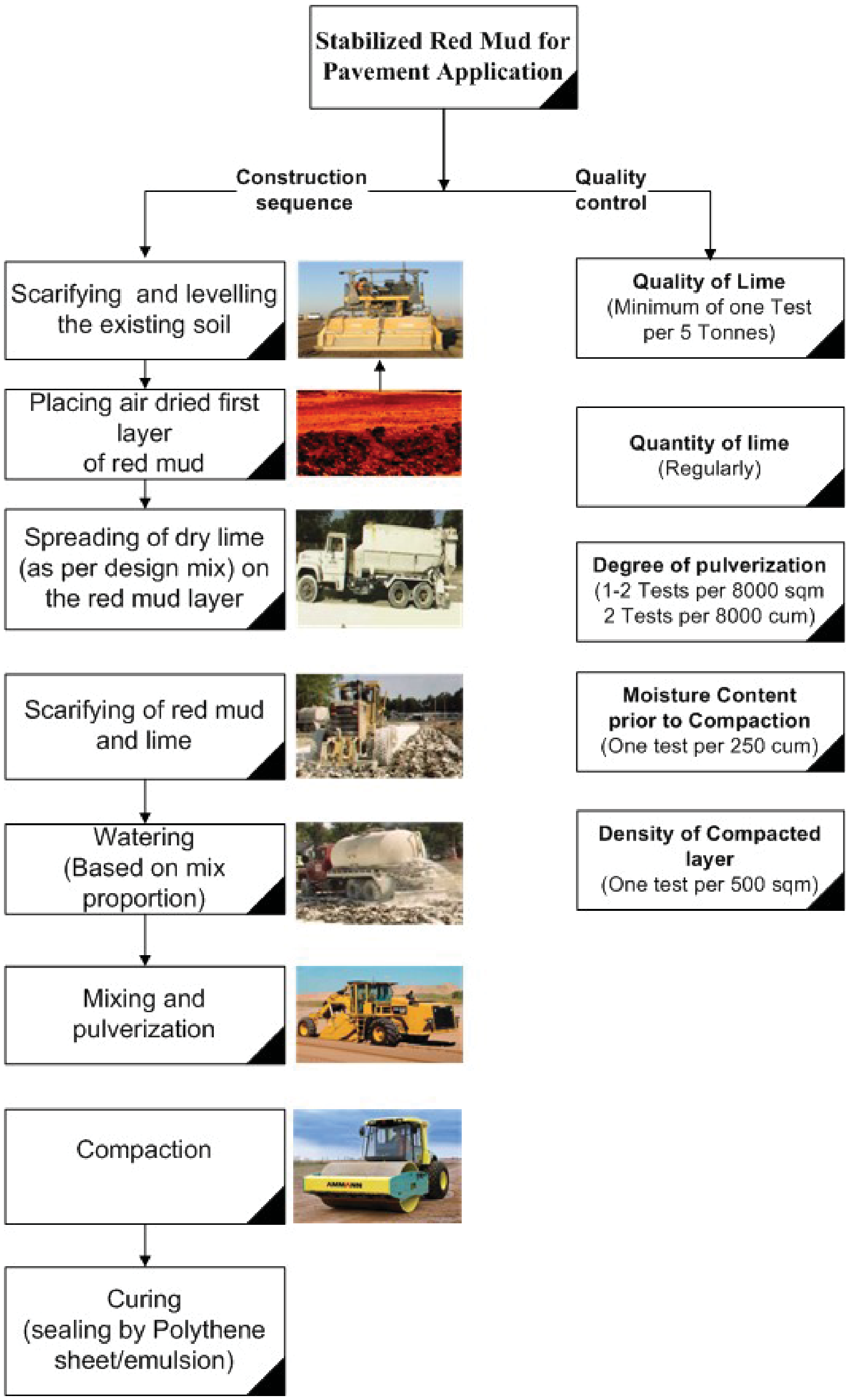


FIGURE 5.4: Flow chart of the sequence of construction and quality control for stabilized red mud for pavement applications (images are for representation purposes only)

pulverizing the existing soil, spreading of red mud and lime, adding water, mixing, compacting to the targeted density and finally curing at the required times before the next layer is placed. Furthermore, the stabilized bed of red mud layer is checked for quality assurance to confirm the quality of construction as per design mix.