

Value added constructional bricks from overburden of opencast coalmines

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This paper presents utilization of waste rock of surface coalmine in making bricks and blocks in place of clay bricks. These bricks and blocks may be used in building construction and as pavement material in and around coalmine. Acidic and alkaline overburden helps in neutralizing acidity or alkalinity of wastewater by making drain with such bricks.

Keywords: Compressive strength, Efflorescence test, Geo-environmental characteristics, Overburden bricks, Sandstone, Shale, Water absorbance percentage, Weathering test

Introduction

Mineral waste utilization¹⁻⁶ as a construction material for making building bricks and blocks has already started in developed and developing countries. In India, marble slurry, tailings and red mud are being suggested to use as a building material⁷⁻¹¹.

Availability and Utilization of Overburden

In India, there are 556 coalmines producing 411 million tonnes (Mt) of coal. Considering geo-mining conditions, surface mining technology is most appropriate and only 164 surface mines with 33 mixed mines are responsible for major production of coal (80%), which is being contributed by 30 open cast mining projects only. Technology used in opencast mining include walking draglines, shovel dumper combine, surface miners in pit crushing and conveying. Surface mines are producing about 328 Mt coal along with huge quantity of overburden waste rocks as mine spoil (Table 1).

There is 84 million m³ (Mm³) annual overburden removal with an accumulation of 916 Mm³ since 1990 only in one coal company of India (South Eastern Coal field Ltd., SECL). This volume of overburden is going to accredited every year due to dumping of overburden, increase of depth of coal seam and coal production (Table 1). If only 60% of total overburden (535.08 Mm³) is utilized for making bricks, about 160524 million bricks

may be constructed from 321 Mm³ overburden per year (Table 1). As mines are well dispersed in Andhra Pradesh, Assam, Chhattisgarh, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, West Bengal and Uttar Pradesh, there will be proper distribution of bricks made with overburden for building and other purposes.

Utilization of mine spoil for constructional bricks and blocks will generate additional employment during and after mine operation. Waste rock utilization in coal mining area reduce environmental impact, more availability of land resource and reduction in mining cost, which occurs on the maintenance of mine spoil as reclamation, plantation, slope stability etc. The plantation will be more effective and cheap in plain land than unstable sloppy dumps¹²⁻¹⁶. Utilization of mine spoil for manufacture of constructional bricks will also conserve precious soil used in making clay bricks.

Characteristics of Overburden for Building Bricks Material

Overburden is composed of mostly friable sandstone, a little shale, and fired clay and rarely conglomerate at few places. Textural analysis of overburden (sandstone) may divide mine-spoil as: i) coarse grain sandstone (> 5 mm grain size); ii) medium grain sandstone (1-5 mm grain size); and iii) fine grain sandstone (< 1 mm grain size). There are mostly medium grained and fine grained sandstones. Major mineral constituents are quartz, cementing material and minor amount of feldspar, Mica and a few grains of heavy minerals are also present

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Table 1—Coal production and overburden removal from mines

Sl No.	Name of company	No. of surface mines	Total annual production of coal Million Tonnes	Annual production of overburden Million m ³	No. of bricks may be produced annually from overburden Million*
1	BCCL	15	17.83	44.23	13269
2	CCL	35	18.20	50.00	15000
3	ECL	18	21.78	44.87	13461
4	MCL	14	61.59	51.43	15429
5	NCL	08	51.52	133.86	40158
6	NEC	02	0.97	7.67	2301
7	SECL	19	66.50	84.38	25314
8	WCL	33	33.16	118.64	35592
	CIL	144	297.56	535.08	
				321.05 (60% of total)	160524

* Assuming only 60% overburden utilization for bricks construction.

Table 2—Mineralogical variation in overburden waste rock (sandstone).

Minerals	Medium grained sandstone		Fine grained sandstone	
	Range	Average	Range	Average
Quartz	52.3 - 58.1	54.1	47.1 - 50.6	49.2
Cement/Matrix	23.0 - 39.3	30.3	36.2 - 44.4	41.0
Feldspar	8.1 - 15.3	10.2	5.6 - 9.2	6.3
Rock fragments	1.0 - 3.2	3.0	0 - 1.2	0.6
Mica	0.8 - 3.3	1.3	1.1-4.6	2.2
Heavy minerals	0 - 0.6	0.5	0.5-0.3	0.2

(Table 2). Argillaceous and ferruginous materials form the main matrix. Sandstone has 18 - 41% clay mineral as matrix material. Favorable property of overburden as raw material for bricks is rich content of clay either as cementing material or as clay or shale (Table 2). Soils/material used for manufacture of bricks¹⁷ should satisfy following requirements: i) Organic matter should not exceed 0.3%; ii) Sulphate content of soil/material, expressed as sodium sulphate should not be more than 0.2%; iii) Fraction retained in sieve (0.075 mm) should not be more than 20% and maximum size of granular material should not exceed 20 mm (Table 3); and iv) Soil/material for bricks should have plasticity index between 7 and 12.

This paper presents production of construction bricks from waste rocks and fly ash. Geo-technical properties of bricks were matched with standard burnt clay bricks.

Materials and Methods

Preparation of Mixture for Making Bricks

Rock samples were crushed and ground to reduce big fragments into smaller size by roll crusher (specification¹⁷: doubled roll, gape less than 20 mm). Mixture of sandstone and other rocks were crushed and ground for mixture preparation as per bricks specification. A mortar of crushed overburden with water was prepared and kept wet for 8-10 h for proper mixing and soaking of water. Then, mortar of overburden filled in moulds of cuboids (made of wood) for producing green bricks at kiln site. Mould is overturned and green brick thus obtained were sun dried for 6-8 days. Then, bricks were baked in a kiln at 800-1200°C, allowed to cool for 2 days and brought back to laboratory for tests. Clay bricks baked with overburden bricks were also brought to laboratory for tests.

Table 3—Dimension, weight, specific gravity and water absorbance of burnt overburden bricks and clay burnt bricks

Sl No.	Length cm	Breadth cm	Height cm	Weight g	Specific gravity g/cc	Water absorbance %	Compressive strength N/mm ²
Overburden burnt bricks							
1	23.5	11.4	7.1	3616	1.90	13.6	4.63
2	23.4	11.4	7.4	3440	1.74	13.2	4.72
3	23.4	11.4	7.2	3364	1.75	8.7	6.49
4	23.4	11.5	6.5	3254	1.85	6.5	7.66
5	23.5	11.5	7.5	3494	1.72	7.9	14.06
6	22.6	10.5	7.5	3409	1.92	7.8	8.06
7	23.3	11.2	7.3	3419	1.79	7.6	7.85
8	23.5	11.0	7.1	3234	1.74	7.8	11.94
9	22.9	11.3	7.2	3441	1.85	21.6	11.40
10	23.0	11.2	7.3	3294	1.75	20.2	12.4
11	23.1	11.0	7.2	3321	1.81	19.3	4.59
12	23.2	11.3	7.2	3380	1.79	3.4	8.28
Clay burnt bricks							
1	22.9	11.4	7.3	3074	1.61	3.7	5.5
2	23.4	11.2	7.2	3064	1.62	7.2	5.7
3	23.5	11.3	7.1	3098	1.64	8.1	5.9
4	23.4	11.4	7.2	2701	1.40	6.7	5.6
5	23.3	11.2	7.3	2750	1.44	9.9	6.0
6	23.4	11.0	7.3	2768	1.47	9.4	13.8
7	23.4	11.0	7.2	3016	1.62	9.4	14.4
8	23.5	11.3	7.2	2872	1.50	9.0	13.8
9	23.5	11.3	7.1	2988	1.58	10.1	13.7
10	23.4	11.2	7.2	3076	1.63	9.8	14.2
11	22.9	11.1	7.3	3089	1.66	13.8	12.6
12	23.2	11.3	7.3	3108	1.62	3.6	14.9

Determination of Geotechnical Properties of Bricks

Geotechnical properties [dimensional conformity, moisture absorbance (MAP), efflorescence & weathering tests, specific gravity and compressive strength] of overburden, made from burnt overburden bricks, were determined and compared with standard clay bricks. Dimensional conformity was fixed by using standard moulds for bricks. Green bricks were produced from standard dimension¹⁸ of moulds (230 mm x 110 mm x 75 mm). Bricks (12 bricks made of overburden, 12 bricks made of clay) were dried in oven at $110 \pm 5^\circ\text{C}$ for 24 h. After that, weight of each brick was taken. Then, bricks were immersed completely in clean water at room temperature for 24 h, wiped with damp cloth and weighed. MAP percentage was determined by standard prescribed procedure¹⁹ as

$$MAP = 100 \times \frac{(b - a)}{a}$$

where, b = weight of bricks after 24 h immersion in clear water and a = weight of dry bricks.

Weathering test of bricks were done in laboratory as per procedure^{19,20}. Two groups of bricks were selected from the sample lot. Then, two groups of bricks were designated as brick A and brick B. Brick A was dried at $110 \pm 5^\circ\text{C}$ for 12 h, and after that weight was taken. Experiment was repeated several times to get constant weight. Oven dry weight (W_d) of brick B was also taken. Brick B was submerged in water at room temperature for 6 h, removed bricks from water and placed in an oven at 71°C for 42 h and then removed all bricks from oven. Brushed all areas of brick twice with wire brush. Strokes were applied to the full height and width of the brick with a firm stroke corresponding to 1.5 kg force. Vertical brush strokes (18-20 times) were given to cover the sides of brick twice, and four strokes were given on each end. One cycle was completed in 48 h of weathering test and this procedure was continued for 12 cycles. After this, brushed bricks were dried at $110 \pm 5^\circ\text{C}$ and weighing

was done until constant weight of brick was found. Final oven dry weight (W_f) was calculated. Calculations of soil loss of bricks were done after prescribed 12 cycle test. Soil loss of brick was calculated in percentage (Table 4) as

$$\text{Soil loss percentage} = (W_i - W_f) \times 100/W_i$$

Weight and specific gravity of individual bricks of overburden and clay were determined by standard prescribed techniques¹⁹ (Table 3).

Determination of compressive strength of bricks was done as per procedure¹⁹. Frogs of each bricks were filled with one part of Portland cement and three parts of clean coarse sand graded particle (size, $d \leq 3$ mm) as per procedure¹⁹. Frogs of each brick were filled by a paste of cement and sand (1:3). This is essentially required to provide uniform surface area during loading. This plane surface also distributes applied compressive load. All bricks were damped cured and soaked in water for 72 h prior to test. Bricks were placed with flat surfaces horizontal and filled face facing upward with three plywood sheets (3 mm thickness) or some soft packing. Bricks were carefully centered between faces of testing machine (model: AIMIL-200 MT capacity). The load

(14 kg/cm² min) was applied axially without shock until failure occurs. Compressive strength was calculated (Table 4).

Results and Discussion

Dimensional Conformity and General Characters of Bricks

For convenience in handling, transportation and laying down of bricks, bricks must be light and small enough to be picked up by masons and laborers using only one hand. For convenience of gripping, brick dimensions are: width, 10; and length, 20 cm. This allows bricks to be paid bonded in a structure to increase its stability and strength. In India, common dimension (223 mm x 100 mm x 75 mm) size is most convenient for handling and construction. Bricks produced with overburden (230 mm x 110 mm x 75 mm) have very slight variation in dimension (Table 3).

Table 4—Grades of burnt overburden bricks

Grades	Water absorbance	Remark
Grade-1	Very good bricks	>5-10% water absorbance
Grade-2	Good bricks	<5% water absorbance.
Grade-3	Very fair bricks	>10-15% water absorbance
Grade-4	Fair bricks	>15-20% water absorbance
Grade-5	Poor quality bricks	>20% water absorbance

Table 5—Material (soil) loss percentage bricks

Sl No.	Weight of oven dry bricks, g	Weight of oven dry bricks after weathering, g	Material loss g	Material loss %
1	3414	3267	0.149	4.36
2	3440	3216	0.224	6.51
3	3364	3200	0.164	4.87
4	3254	3108	0.146	4.49
5	3494	3196	0.298	8.53
6	3406	3294	0.112	3.29
7	3419	3408	0.111	3.25
8	3234	3062	0.172	5.32
9	3441	3334	0.107	3.12
10	3374	3184	0.190	5.63
11	3464	3318	0.146	4.21
12	3398	3169	0.229	6.73
13	3401	3311	0.090	2.65
14	3357	3296	0.061	1.82
15	3468	3314	0.154	4.44
16	3.416	3368	0.048	1.41
17	3372	3294	0.078	2.31
18	3494	3247	0.247	7.07
19	3322	3198	0.124	3.73
Standard bricks				
20	2705	2480	0.225	8.3
21	2698	2387	0.311	11.52
22	2725	2366	0.359	13.17
23	2700	2470	0.230	8.52
24	2629	2310	0.319	12.13

Water Absorbance Percentage of Overburden Bricks

In bricks made with overburden, water absorbance percentage is not more than 10%. Water absorbance for general bricks should be less than 20% and for first class bricks, it should be less than 15% as per prescribed standard. Water absorbance (3.4-21.6 %) for burnt overburden bricks (Table 3) is almost in same range of burnt clay bricks. Burnt overburden bricks may be divided on the basis of water absorbance percentage (Table 4). Burnt overburden bricks are not inferior than burnt clay bricks and grade-1 overburden bricks are better than traditional burnt clay bricks (Table 4).

Efflorescence and Weathering Tests

Efflorescence is a deposition of water-soluble salts on the surface of brick. It is neither harmful to brick masonry nor it affects structural integrity of construction. Bricks with high efflorescence may be used for making drain for discharge of acidic water of coalmines. If it is used in other construction, in extreme cases of efflorescence, a thin layer of poultice can be applied to masonry surface after cleaning. This will draw salt out beyond the brick surface. Poultice can be washed off with clean water. Overall, alkalinity of bricks will not

be a problem in construction where water seepage is least. Burnt overburden bricks show efflorescence in very slight range and hence, it has property of good bricks. Weathering test of bricks (overburden and clay) was conducted as per IS standard^{9,20}. It may be observed (Table 5) that soil loss due to water seepage is more. In other words, resistance offered by burnt clay bricks to disintegration when came in contact with water is more than burnt overburden bricks. Hence, overburden bricks are superior to traditional clay bricks.

Specific Gravity and Weight

There is slight increase in specific gravity of bricks made from overburden (Table 3). High quartz content is responsible for high density of overburden bricks but simultaneously it produces more strength to bricks. Specific gravity of standard clay bricks (1.40 - 1.66 g/cc) is lower than that of overburden bricks (1.72-1.90 g/cc). Specific gravity may decrease by making perforated bricks if desired. Depending upon density and weight, bricks may be classified as solid (<25% perforation by vol, although, bricks may be frogged, having indentations on one of the longer faces), perforated (containing a pattern of small holes through brick, up to 25% by vol), cellular (containing a pattern

Table- 6—Comparison of cost of bricks made by clay and overburden manual methods

S No.	Techno-economic parameters	For burnt clay bricks	For burnt overburden bricks	Remark
1	Cost of land (soil), Rs/m ³	60	Nil	No cost
2.	Cost of mould making, Rs./1000 bricks	Rs 150-160	Rs 200	Costly
3	Cost of transportation of green bricks, Rs./1000 bricks	Rs 40/-	Rs 60	Very cheap
4	Total coal consumption, Rs/1000 bricks	500	250	Costly
	kg/1000 bricks	100	100	
5	Drying	Natural air & Sun drying	Natural air and intense sun drying	More in sun drying in open near mine
6	Man power required at kiln	1 fire master 3 fire man per shift	1 fire master 3 fire man per shift	Same
7	Man power required in moulding	6 person	7 person	For mixing etc. one more person required
8	Typical soil	Sandy silt	Sandy mixture	Better than soil
9	Rated output of moulding	4000 bricks/day	5000 bricks/day	Because material is loose
10	Transportation cost of bricks to mine site and surrounding area, Rs/1000 bricks	Very high Rs 400	Very low Rs 100	Lower than burnt clay bricks
	*Actual cost of bricks, Rs/1000 bricks	1100	610	

*Without kiln/ chimney and other costs, which will be common in both cases. Crushing cost of overburden is also not included

of holes removing > 20% of vol, but closed on one face) or hallow (containing a pattern of large holes removing > 25% of bricks vol). In many construction works, high density of bricks is considered as a demerit. Hence, for specific purposes, perforated bricks may be made to decrease density of burnt overburden bricks without compromising with compressive strength. However, for low cost housing for people in such remote area, these bricks will be a boon.

Compressive Strength of Burnt Overburden Bricks

Compressive strength of burnt overburden bricks (4.59 - 15.80 N/mm²) is slightly higher than ordinary clay bricks (Table 3). Clay bricks prepared in USA, also ranges from 7 to 105 mega Pascal and are being used accordingly at different construction points. In UK, clay bricks have compressive strength as high as 100 mega Pascal (100 N/mm²), although common clay bricks range in India is lower (4-15 N/mm²), indicating that bricks made from overburden have significant compressive strength for use in various construction projects.

Techno-Economic Feasibility of Burnt Overburden Bricks

Burnt overburden bricks have several favourable properties as a construction material (Table 6). Dimensional conformity and compressive strength also make these bricks superior than conventional burnt clay bricks. Comparison of techno-economic analysis of bricks also suggests that it can be utilized at various construction site. Bricks are viable geo-technically and economically also.

Conclusions

Overburden bricks are better than conventional burnt clay bricks in terms of compressive strength, efflorescence & weathering tests, water absorbance etc. However, specific gravity of overburden bricks is slightly higher than conventional bricks. Though, it will not be a major demerit particularly for low cost housing for poor people and boundaries and other low height structures around mining complex.

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