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GOLD TAILING

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Gold tailing—A suitable siliceous waste for the manufacture of calcium silicate bricks

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Gold tailing, a waste material of gold ore beneficiation plants is a fine siliceous material, which at present has no potential use, can be utilized for producing calcium silicate bricks. The laboratory results show that the bricks of compressive strength 100-150 kg/cm^2 can be produced by using 90 per cent tailing and 10 per cent lime, by shaping the bricks at 240 kg/cm^2 and autoclaving them at 14 kg/cm^2. The strength of bricks is further improved by replacing 10-30 per cent tailing by sand. The formation of tobermorite (11 Å type calcium silicate hydrate) in the autoclaved bricks has been identified, which possibly contributed to strength development.

Autoclaved calcium silicate brick, popularly known as sand lime brick, is an alternative to other walling materials such as red burnt brick and stone masonry block, particularly suitable for use in those areas where good quality clay bricks are not being manufactured and sand or siliceous waste like flyash, blast furnace slag or ore tailings, etc. are available. Further the calcium silicate brick technology enables the utilization of mining and industrial wastes as tailings from gold, copper, iron, zinc, flyash, etc. which are otherwise a health hazard and their disposal is a serious problem. In India, the production of such bricks is insignificantly low as only one plant in Kerala is operating to manufacture 10 million bricks per year whereas 30 billion bricks are annually being manufactured in European countries[1].

In the process technology for the production of calcium silicate bricks, sand or siliceous waste is mixed with a small proportion of lime and just sufficient water to mould bricks under pressure, and steam cured (autoclaved) at high pressures. During mixing, the sand grains get coated with lime which on autoclaving react to form cementing compounds such as CSH(II), CSH(I), tobermorite, gyrolite, etc.[2] while on steam curing at normal pressure compounds formed are gelatinous, providing low grade binding characteristics[3].

The strength of calcium silicate bricks depends on many factors like physico-chemical characteristics of raw materials, degree of compaction, autoclaving conditions such as pressure and duration.

It has been reported[4] that a promising material suitable for the production of calcium silicate building materials, requires a minimum of 50 per cent of silica which has invariably been found to occur in some of the mining wastes. In India about 0.50 million tonnes of gold tailings are produced annually at Hutti and Kolar gold mines and its disposal is an acute problem. The waste material, constituting nearly 99% of the rock ore obtained on beneficiation, has been examined as an alternate to fine sand for the production of calcium silicate products. This waste, otherwise, is a health hazard contributing to pollution and is normally discharged into ponds, drains and dams wherein the effluents settle and solidify.

Many researchers[5-10] have reported the approaches for the utilization of these tailings for producing various types of building materials. Watanabe *et al.*[5] have recommended the production of autoclaved concrete by replacing 40 per cent cement by these tailings. Richard *et al.*[6] have reported that high strength bricks can be produced by using 10 per cent hydrated lime as binder followed by pressing at 400 kg/cm^2 pressure and autoclaving at 12 kg/cm^2 for 8 h. Tailings from different ores like gold, nickel, copper and uranium with 12 per cent lime have also been utilized to shape bricks of high strength (170-510 kg/cm^2), by pressing at 360 kg/cm^2 and autoclaving at 14 kg/cm^2 for 6 h[7]. Hansen[8] has reported the feasibility of utilization of gold tailing with Portland cement as binder for the production of autoclaved calcium silicate bricks under the hydrothermal conditions at 10 kg/cm^2 steam pressure for 6 h duration.

The preliminary studies[9] have been carried out for the utilization of gold tailing from Bharat Gold Mines, Kolar for manufacturing such type of bricks. The data based on briquettes made with tailing and hydrated lime in different proportions, moulded at 300 kg/cm^2 and autoclaved at 14 kg/cm^2 for 5 h, indicate that the briquettes of compressive strength 155 to 300 kg/cm^2 can be produced. The 10-20% addition of sand did not show any improvement in the strength of briquettes. Although no scientific explanations or data have been given for the strength development in autoclaved specimens or the neutral behaviour of sand used in this study. The suitability of gold tailing from the same source for producing masonry cement[10] has also been studied. The results obtained indicate that the masonry cement, prepared from a mix containing 40 per cent portland cement and 60 per cent tailing, is most suitable. Although this cement has slightly lower water retention and air content values as compared to IS: specification (IS: 3466-1988).

In the present study, gold tailing from two sources namely Hutti Gold Mines, Hutti (HG) and Kolar Gold Fields, Kolar (KG) have been evaluated for their suitability for producing calcium silicate bricks. The data presented in this paper, mainly based on tailing from Hutti, show the variation of compressive strength of bricks with different parameters such as lime content, autoclaving condition and particle size distribution of mix compositions. The results obtained have been substantiated with the scientific data obtained from chemical analysis, differential thermal analysis and X-ray diffraction.

Experimental Procedure

Various physico-chemical characteristics like particle size analysis, specific gravity, chemical and mineralogical compositions of Hutti and Kolar Gold tailings marked as HG and KG respectively were determined by the standard methods.

Different mix compositions consisting of tailings and lime with and without locally available sand were prepared and full size bricks of size 19×9×9 cm were moulded at the forming pressure of 240 kg/cm^2 in a hydraulic press of capacity 400 bricks/h developed at this Institute (Fig. 1). The moulded bricks were autoclaved at different pressures ranging from 5 to 14 kg/cm^2 for 6 h.

The characteristics like compressive strength, water absorption and bulk density of the autoclaved bricks were determined as per standard procedure (IS: 4139-1989). The extent of reaction occurring between lime and tailings was determined by estimating free lime and soluble silica content in the autoclaved specimens by standard procedures[11,12].

The identification of cementitious phases like CSH(II), CSH(I) or tobermorite, responsible for strength development in bricks, was carried out by subjecting the autoclaved samples to differential thermal analysis (DTA) and X-ray diffraction (XRD). The DTA of samples (−100 mesh) was carried out upto 1000°C by using Stanton Red Croft DTA-674 apparatus, maintaining a heating rate of 10°C/min and using α-Al_2O_3 as the reference material. XRD of these samples (−300 mesh) was obtained by using X-ray diffractometer (Philips PW 1730) with CuK_α target and Ni filter. The scanning rate, chart speed and range was kept at 1°/min, 0.5 cm/min and 2000 C/s respectively.

Results and Discussion

The chemical analysis of the gold tailing samples (Table 1), indicates that the SiO_2 content in these samples varies between 50.79 and 57.42 per cent which meets the specific requirement of 50 per cent silica, recommended for producing calcium silicate bricks[4]. However, the tailings in India are more aluminous and ferruginous in nature, compared to tailings of Japan (Table 1) which are more siliceous and contain a maximum of 5 per cent $Al_2O_3 + Fe_2O_3$. Mineralogically the tailings from Hutti and Kolar mines comprise

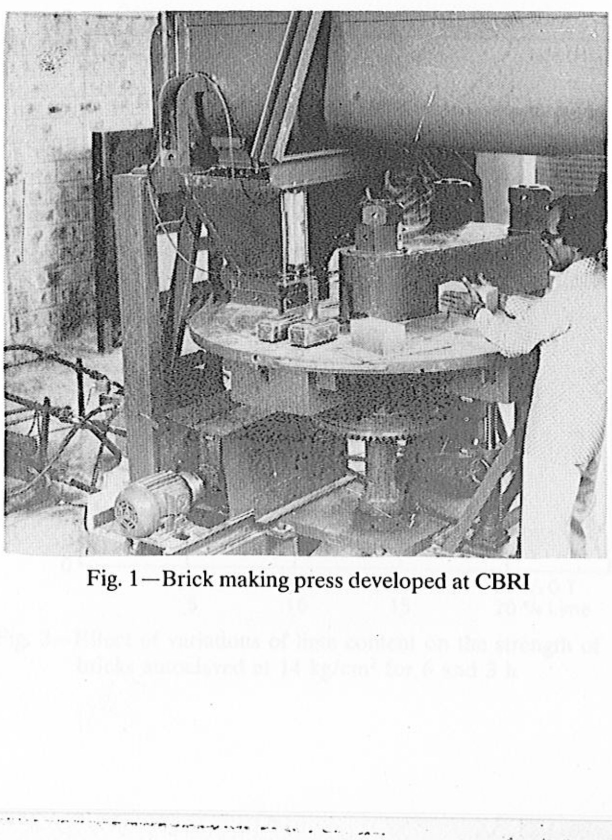

Fig. 1—Brick making press developed at CBRI

quartz as the predominant mineral, biotite, chlorite, muscovite and hornblende are present as accessory constituents.

The particle size analysis of the tailings from Hutti (HG) and Kolar (KG) show them to be extremely fine in nature (Fig. 2) as their 90 per cent fraction passes through 150 μm sieve and the fineness modulus varies between 0.10-0.16. The specific gravity of these tailings varies between 2.85 and 2.90.

The data on full size bricks of different compositions (Table 2) made with Hutti gold tailing and hydrated lime, moulded at 240 kg/cm^2 pressure and autoclaved at 14 kg/cm^2 for 3 and 6 h duration (Fig. 3) indicate that as the lime content in the mix composition of brick increases from 5 to 20 per cent, the compressive strength of the brick also increases from 70 to 217 kg/cm^2. Similarly as the autoclaving pressure of the bricks, having 90 per cent tailing and 10 per cent lime, increases from 5 to 14 kg/cm^2 with 6 h retention time at the maximum steam pressure, the strength of the brick also increases from 58 to 150 kg/cm^2 (Fig. 4). In the case of bricks made with 95 per cent tailing and 5 per cent lime, the strength increases from 30 to 80 kg/cm^2.

The XRD of samples (Figs 5-7), containing 90

Table 1—Chemical composition of gold tailings from different origins

Constituents	Hutti Gold Mines (%)	Mysore Mines (%)	Nundydroog (%)	Yappamana Mines (%)	Japan Mines (%)
LOI	4.60	1.54	1.74	13.66	12.0-14.0
SiO_2	50.79	57.42	52.90	41.00	66.0-75.0
Al_2O_3	23.10	15.00	13.50	18.12	2.0-3.0
Fe_2O_3	11.21	6.75	14.70	11.98	1.0-2.0
TiO_2	0.60	0.55	0.51	0.42	—
CaO	3.16	18.89	10.08	9.02	10.0-20.0
MgO	2.54	6.44	4.99	4.68	—

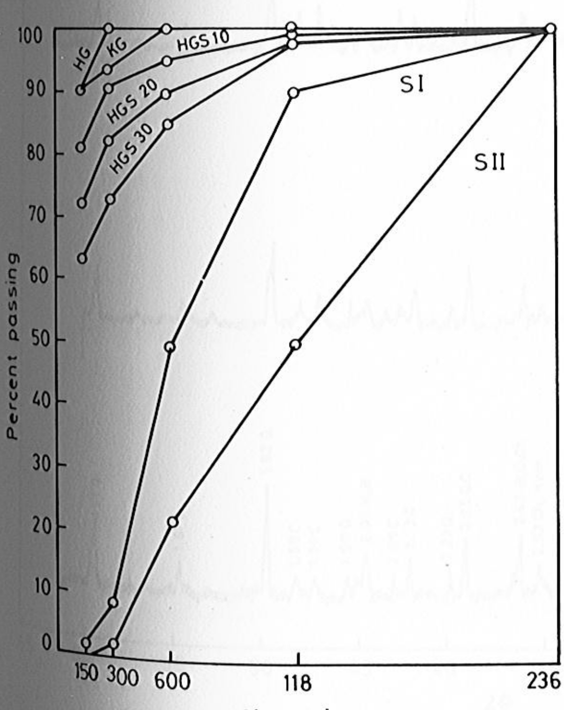

Fig. 2—Particle size analysis of gold tailings, sand and their mixes used in bricks

Table 2—Mix compositions of gold tailings and lime with and without sand

Mix composition (% by wt)			Autoclaving pressure (kg/cm^2)
Tailing	Lime	Sand	
95	5	—	5, 8, 10, 12 and 14
90	10	—	,,
85	15	—	,,
80	20	—	,,
80	10	10	,,
70	10	20	,,
60	10	30	,,

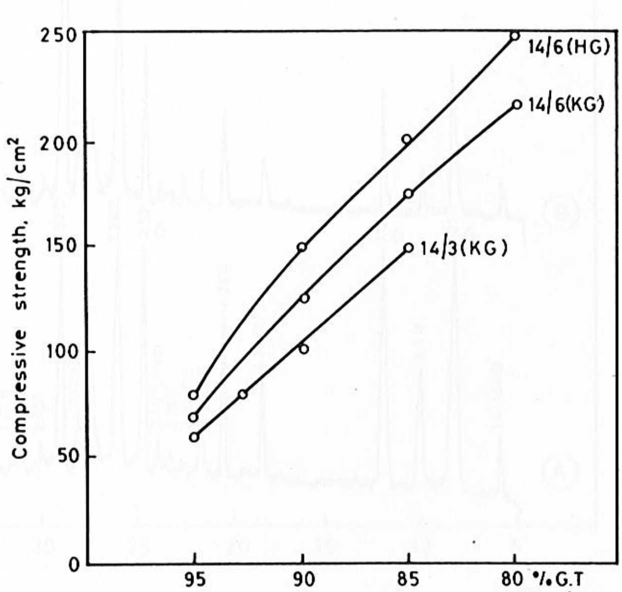

Fig. 3—Effect of variations of lime content on the strength of bricks autoclaved at 14 kg/cm^2 for 6 and 3 h

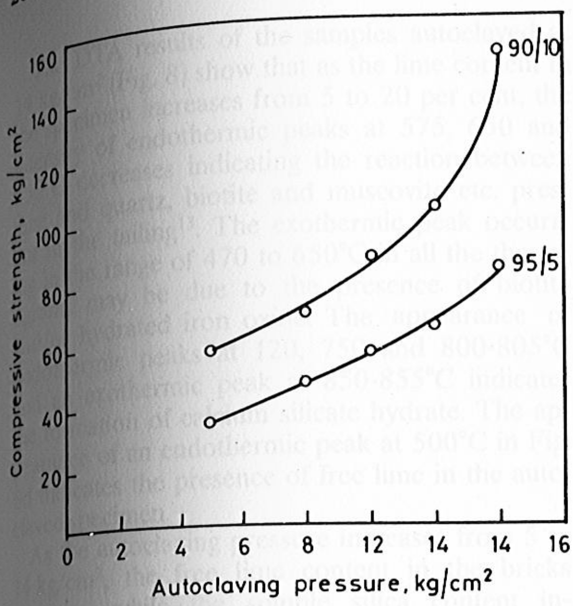

Fig. 4—Variation of compressive strength of brick with autoclaving pressure

per cent tailing and 10 per cent lime and autoclaved at 5 to 14 kg/cm^2, indicate that at low pressure upto 10 kg/cm^2, the diffractograms show the peaks at 3.28, 3.07, 2.98, 2.59, 2.56, 2.08 and 1.82Å indicating the presence of dicalcium silicate hydrate and monocalcium silicate hydrate cementitious phases. The intensities of peaks attributable to quartz (4.28, 3.34, 2.28, 1.82Å), muscovite (10.2, 3.34, 2.03Å), biotite (10.2, 3.34, 2.66, 2.45, 1.54Å) and chlorite (14.2, 7.07, 4.79, 3.53, 2.83, 2.52Å), are gradually reduced as their reactions with lime during autoclaving increases with increasing autoclaving pressure. As the autoclaving pressure increases in steps from 8, 10, 12 to 14 kg/cm^2 and the increase of lime content from 5 to 20 per cent, the peaks at 11.2, 3.07, 2.98, 2.07 and 1.83 become more prominent, indicating the gradual formation of crystalline tobermorite. The iron oxide present in the form of hematite in these tailings does not react with lime under these conditions and acts as an inert constituent.

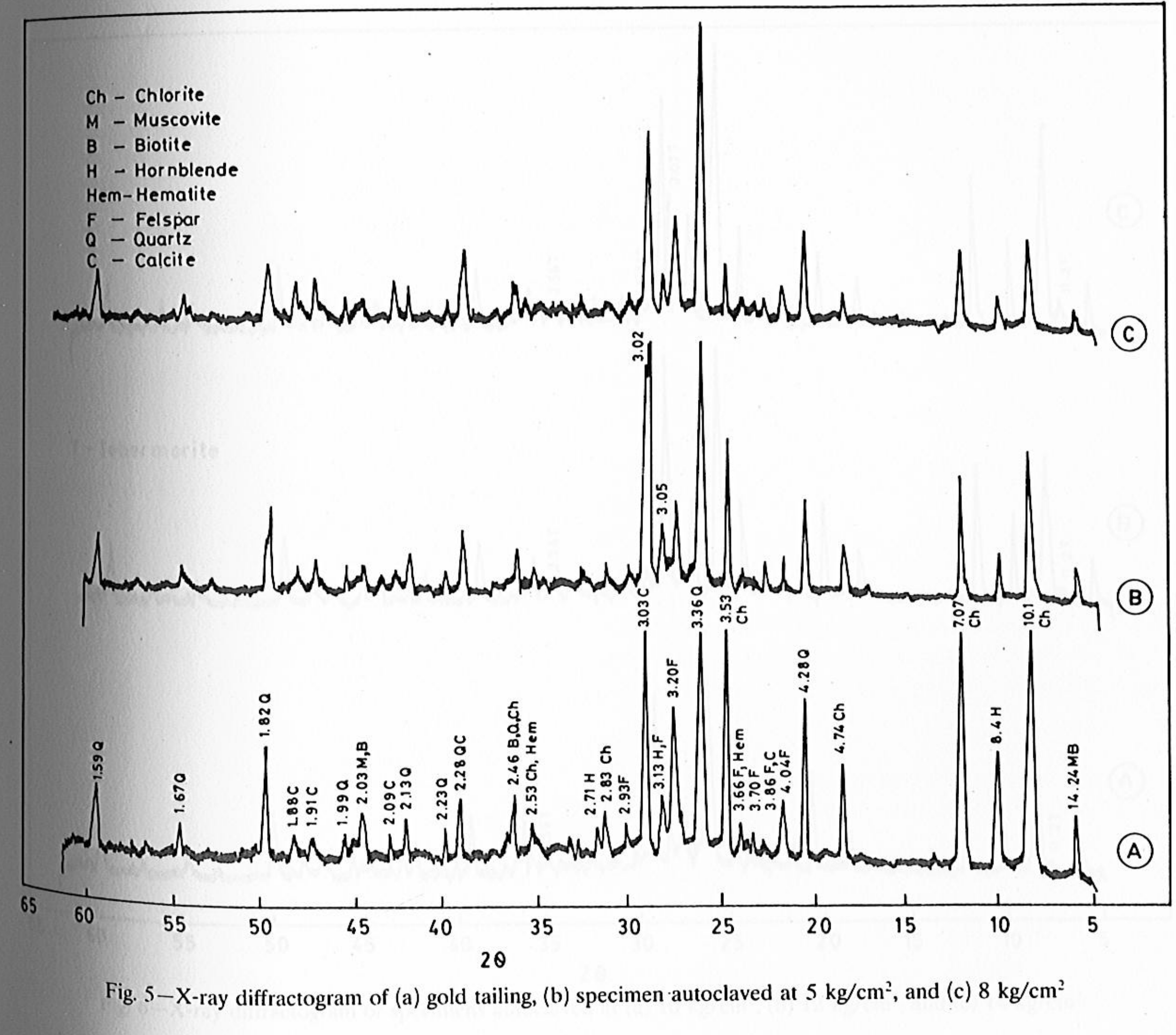

Fig. 5—X-ray diffractogram of (a) gold tailing, (b) specimen autoclaved at 5 kg/cm^2, and (c) 8 kg/cm^2

The DTA results of the samples autoclaved at 14 kg/cm^2 (Fig. 8) show that as the lime content in the specimen increases from 5 to 20 per cent, the intensity of endothermic peaks at 575, 650 and 850°C decreases indicating the reaction between lime and quartz, biotite and muscovite etc. present in the tailing[13]. The exothermic peak occurring in the range of 470 to 650°C in all the thermograms may be due to the presence of biotite and/or hydrated iron oxide. The appearance of endothermic peaks at 120, 750 and 800-805°C and an exothermic peak at 850-855°C indicates the formation of calcium silicate hydrate. The appearance of an endothermic peak at 500°C in Fig. 8d indicates the presence of free lime in the autoclaved specimen.

As the autoclaving pressure increases from 5 to 14 kg/cm^2, the free lime content in the bricks decreases while the soluble silica content increases (Figs 9 and 10), indicating the progressive reaction of lime with silica contained in tailings.

The effect of sand addition—Since these tailings are very fine (< 150 micron) with a narrow range of particle size distribution, the strength of bricks was found to be in the range of 58 to 150 kg/cm^2. But by replacing 10 to 30 per cent tailing (HG) with locally available coarse sand S_1 (F.M. 2.50), with mixes marked HGS 10, HGS 20 and HGS 30, (Table 3) the strength of bricks increases to the range of 70-180 kg/cm^2 under same conditions, which may be due to wider range of particle size distribution (Fig. 2) as well as due to more formation of CSH, although no chemical data is available to show this effect. Possibly this results to better compaction, increased bulk density and decreased water absorption. These results suggest that besides the moulding, autoclaving pressures, retention time, and the compaction, grading of the particles are also critical to develop high strength autoclaved products[14].

Similar studies were conducted with another sample of gold tailing (KG), collected from Kolar

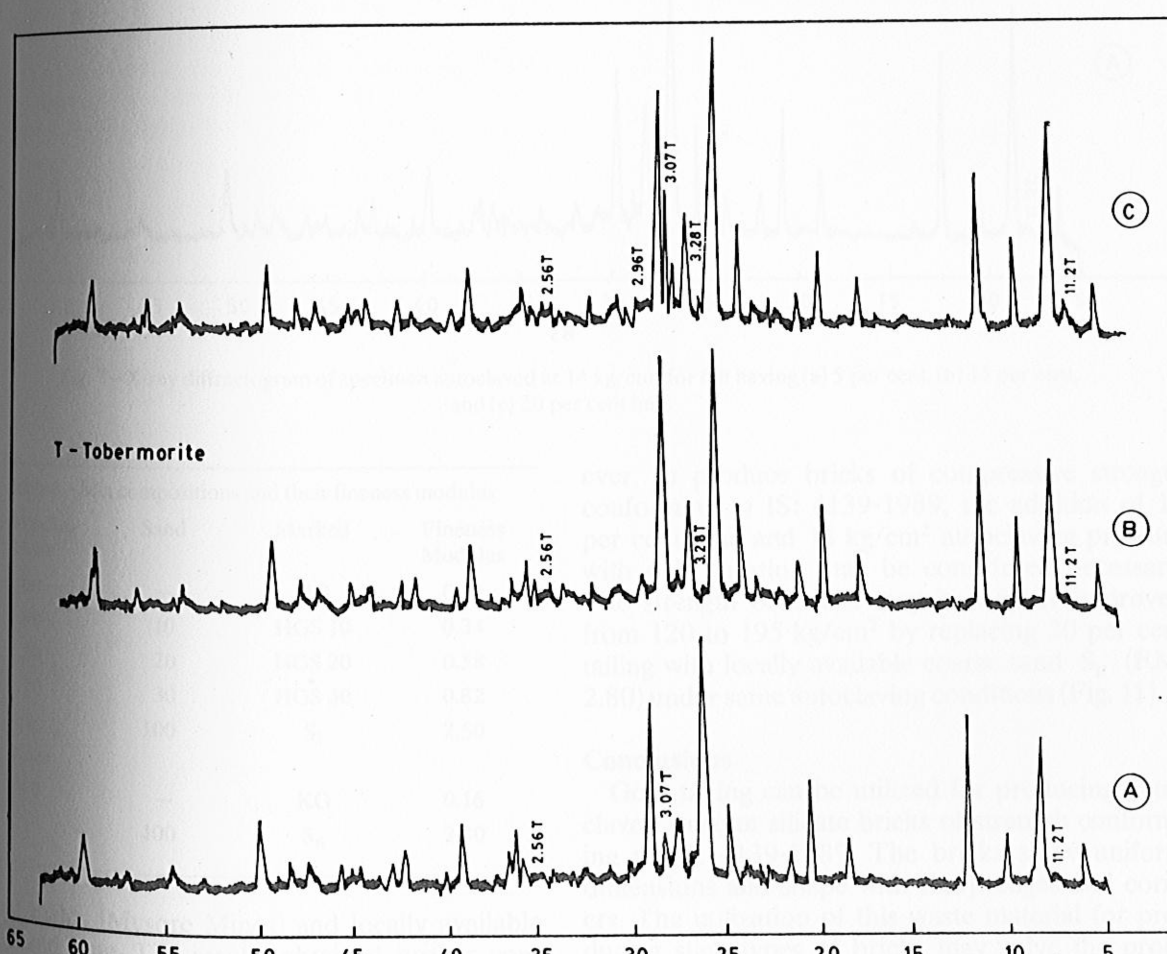

Fig. 6—X-ray diffractogram of specimens autoclaved at (a) 10 kg/cm^2, (b) 12 kg/cm^2, and (c) 14 kg/cm^2

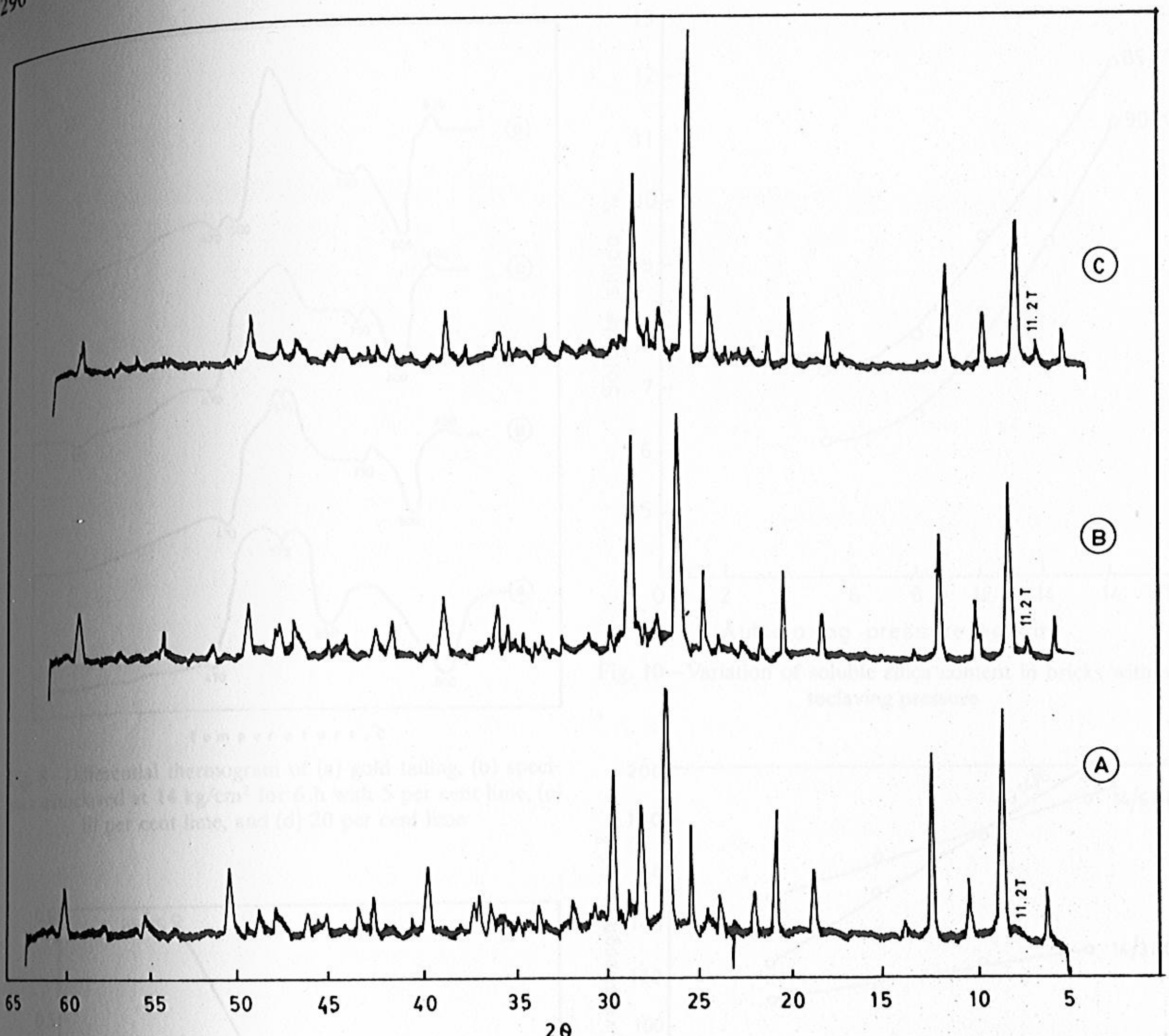

Fig. 7—X-ray diffractogram of specimen autoclaved at 14 kg/cm^2 for 6 h having (a) 5 per cent, (b) 15 per cent, and (c) 20 per cent lime

Table 3—Mix compositions and their fineness modulus

Gold tailing Hutti	Sand	Marked	Fineness Modulus
100	—	HG	0.10
90	10	HGS 10	0.34
80	20	HGS 20	0.58
70	30	HGS 30	0.82
—	100	S_I	2.50
Kolar			
100	—	KG	0.16
—	100	S_{II}	2.80

Gold Fields (Mysore Mines) and locally available sand and lime. The results obtained further confirm that as the addition of lime increases the strength of bricks also increases (Fig. 3). However, to produce bricks of compressive strength conforming to IS: 4139-1989, the addition of 10 per cent lime and 14 kg/cm^2 autoclaving pressure with 6 h duration may be considered necessary. The strength of bricks may be further improved from 120 to 195 kg/cm^2 by replacing 30 per cent tailing with locally available coarse sand S_{II} (F.M. 2.80) under same autoclaving conditions (Fig. 11).

Conclusions

Gold tailing can be utilized for producing autoclaved calcium silicate bricks of strength conforming to IS: 4139-1989. The bricks show uniform dimensions and shape with sharp edges and corners. The utilization of this waste material for producing such types of bricks may solve the problems of its disposal and air pollution to a great extent. The feasibility study further confirms that

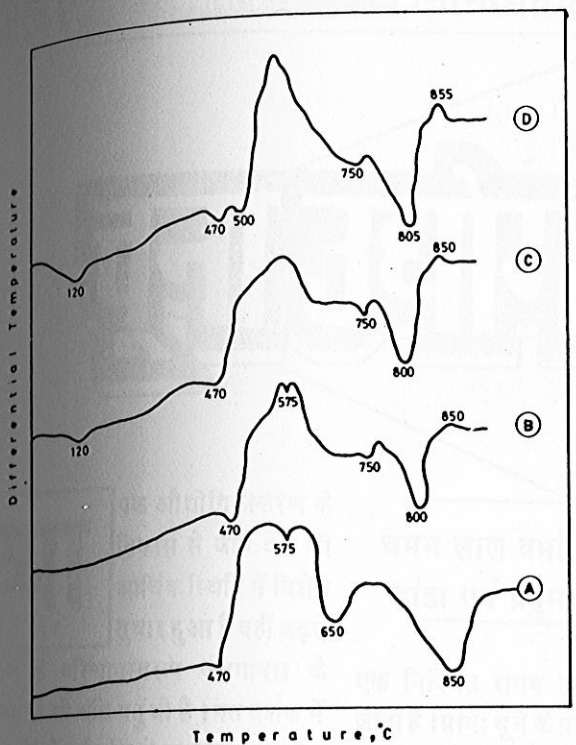

Fig. 8—Differential thermogram of (a) gold tailing, (b) specimen autoclaved at 14 kg/cm² for 6 h with 5 per cent lime, (c) 10 per cent lime, and (d) 20 per cent lime

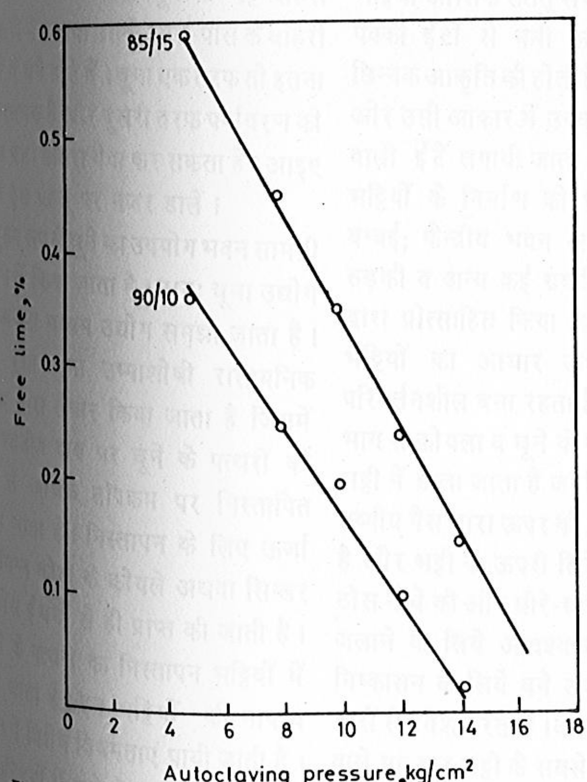

Fig. 9—Variation of free lime content in bricks after autoclaving at different pressures

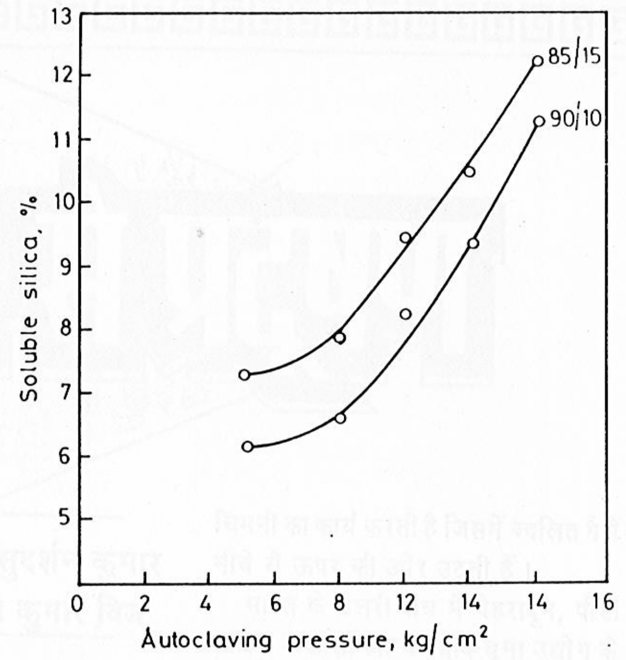

Fig. 10—Variation of soluble silica content in bricks with autoclaving pressure

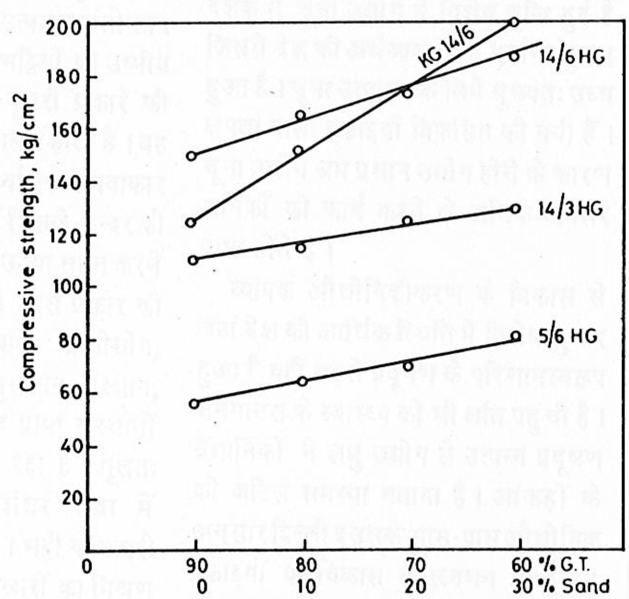

Fig. 11—Variation of compressive strength of bricks with the addition of sand and autoclaved at 5 and 14 kg/cm² for 6 and 3 h

nearly 0.1 million tonnes of gold tailing can be used for producing 30 million bricks per year.

Acknowledgement

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