Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Vol. 9	No. 3	pp. 489-494	2010

Original Research Paper

Investigation on Suitability of Spent Fire Bricks (SFB) in Concrete

R. Srinivasan and S. Keerthinarayana*
Deptt. of Civil Engg., Tamilnadu College of Engineering, Karumatham Patti, Coimbatore-641 659, Tamil Nadu, India
*Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore-641 014, T.N.

Nat. Env. Poll. Tech.
ISSN: 0972-6268
www.neptjournal.com

Key Words:
Fire bricks
Spent fire bricks (SFB)
Crushed spent fire bricks (CSFB)
Natural fine aggregates
Cocrete

ABSTRACT

Concrete is the most undisputable and indispensable material being used in infrastructure development throughout the world. Umpteen varieties of concretes (FAC, HVFAC, FRC, HPC, HSC and others) were researched in several laboratories and brought to the field to suit the specific needs. Although natural fine aggregates i.e., river sand are so far superior to any other material in making concrete; their availability is continuously being depleted due to intentional overexploitation throughout the globe. Hence, partial or full replacement of fine aggregates by other compatible materials like sintered fly ash, crushed rock dust, quarry dust, glass powder, recycled concrete dust, and others is being researched from past two decades in view of conserving the ecological balance. In this direction, a preliminary investigation was undertaken to use "Spent Fire Bricks" (SFB) i.e., waste material from foundry bed and walls and lining of chimney which is adopted in many industries, for partial replacement of sand in making good concrete. The vital objective of this investigation is to assess the utility of SFB in making good concrete by studying its physicochemical and other characteristics.

INTRODUCTION

Aggregates are important constituents in concrete composite that help in reducing shrinkage and impart economy to concrete production. Most of the aggregates used are naturally occurring aggregates such as crush rock, gravel and sand which are usually chemically interactive or inert when bonded together with cement. The modern technological society is generating substantially higher quantities of municipal and industrial solid wastes posing a challenging task of their effective and efficient disposal. During 1970s and 1980s, several environmental agencies began to pay increasing attention to industrial pollution, safety and waste management control as a result of which the foundry industry had to re-evaluate standard practices with regard to the disposal of their used sands. One of the main concerns for the foundry industry has been the need to reduce the disposal cost and minimize the maintenance costs of landfill sites.

Even though, use of several types of industrial solid wastes like metallurgical waste, glass pieces, fly ash, quarry dust, tyre and rubber waste, crushed concrete waste, sludges and others in making good field concrete is being effectively done in European countries, U.S.A., U.K., and Australia; Asian countries could not gear up to that level to match these countries . Therefore, resource exploitation and waste disposal problems are currently rocking the sustainable development in many countries including India. The present study deals with evaluation of feasibility of use of spent fire bricks in preparation of concrete.

MATERIALS AND METHODS

Fire bricks: Fire bricks are the products manufactured (as per IS: 6 and IS: 8 specifications, Greer et al 1987, Heine et al. 1975, Naik 1987) from refractory grog, plastic, and non plastic clays of high purity. The different raw materials are properly homogenized and pressed in high capacity presses to get the desired shape and size. Later, these are fired in oil-fired kiln at a temperature of 1300°C. Table 1 shows the physicochemical properties of the fire bricks. Apart from this, they exhibit excellent non susceptibility to chemicals, thermal shocks and carbon deposits. The sample fire bricks and their application in a typical furnace are shown in Figs. 1 and 2 respectively.

Spent fire bricks (SFB): Due to exposure to continuous high temperature (i.e., 1000-1200ºC) for a period of 10 to 15 days, they lose some of the physical and mechanical properties and need to be replaced by fresh fire bricks. Then, the SFB is an industrial solid waste to be disposal off properly. Fig. 3 shows the broken SFB. The SFB were procured from five different sources in and around Coimbatore. They were physically cleaned and mechanically crushed to a size gradation conforming to fine aggregates (Naik 1987, IS: 383, 1970, IS: 10262, 1981).

Laboratory analysis: All tests pertaining to the physical parameters of sand and crushed spent fire bricks (CSFB) (specific gravity, bulk density, water absorption, fineness modulus) were as per Indian Standard Codes (Naik 1987, IS: 383, 1970, IS: 10262, 1981) and performed in the Laboratory. The chemical analysis of CSFB was carried out in Environmental Cell, Water Technology Division, Tamilnadu Agricultural University (TNAU), Coimbatore.

RESULTS AND DISCUSSION

As the major portion (i.e., 70-75% by volume) of the concrete is of aggregates (both fine and coarse), the long and short term performance of many concretes depend on their physicochemical characteristics (Naik 1987, IS: 383, 1970, IS: 10262, 1981). In view of replacing the fine aggregates by CSFB, the various physicochemical properties and elemental composition were compared with the sand (Tables 2 and 3).

Sand particles generally posses a size range of 4.75 to 0.07mm and for producing a good concrete, ‘single-size’ aggregates are usually preferred. The particle size distribution for sand and five different samples of CSFB are presented in Table 4, and Figs. 4 and 5 respectively. From these

Fig. 1: Fire bricks samples.

Fig. 2: Fire Bricks used in a Typical Furnace.

Fig. 3: Broken fire bricks after complete usage.

distributions, the fineness moduli (FM) were calculated as follows and shown in Table 4.

$$FM = \frac{\Sigma \text{ Cumulative weight fraction retained (\%)}}{100} \quad ...(1)$$

It is seen that both sand and CSFB conform to zone II (as per IS:2386 (part-III)-1963). Further, when observed under high power lenses, CSFB particles were of irregular shapes with sharp edges, which are same as that of natural sand texture. However, detailed SEM analysis is essential to understand their texture, internal pores, pore size, pore volume and pore distribution. Both CSFB and sand appeared to have almost same specific gravity, water absorption and FM, but the bulk density (at both the states) and pH values were significantly different. This is because of the fact that the CSFB is not as inert as that of sand, but does not affect the quality of concrete, which clearly substantiates the suitability of CSFB in making concrete. The FM of CSFB (i.e., 2.5) is almost same as that of FM of sand (i.e., 2.3) used for comparison.

As the durability and strength (i.e., strength-through-durability concept is gaining momentum during past one decade) chiefly depend on the factors like microstructure of particles, alkali-silica reaction, alkali-aggregate reaction, nature and rate of ettingette formation, and others, the knowledge of chemical/elemental composition of the replaced material (i.e., CSFB) is highly necessary. Comparative account of elemental composition of sand and CSFB is given in Table 3. Except iron, calcium, magnesium, sodium and potassium contents in sand are low, but in CSFB the aluminium content is very high. Not much difference in silica, iron and aluminium contents between fire bricks and CSFB were noticed; except a slight increase in calcium content which reveals the usefulness in strength aspect. Further, as the silica deficiency (i.e., about 34.9%) is compensated by the aluminium enhancement (i.e., 34.3%)

Table 1: Physio-chemical properties of the fire bricks.

Property	Values
Physical	
Bulk density	2000 kg/m^3
Porosity	25-30%
Size tolerance	± 2%
Working temperature	1300-1400ºC
Crushing strength (cold)	24.5-27 N/mm^2
Chemical	
Aluminum as Al_2O_3	30-40%
Iron as Fe_2O_3	2-2.5%
Silica as SiO_2	57-65%
Alkalies	Trace

Table 2: Comparison of physio-chemical properties of sand and CSFB.

Parameter	Sand	CSFB					Average
		S1	S2	S3	S4	S5	
Specific gravity	2.31	2.33	2.45	2.23	2.47	2.38	2.37±0.0970
Bulk density, kg/m^3	1247	1306	1355	1296	1322	1295	1315±24.95
	(1509)	(1551)	(1555)	(1498)	(1551)	(1497)	1530±30.07
Moisture content,%	0.03	0.95	0.91	0.96	0.99	0.92	0.95±0.0320
Water absorption,%	0.94	0.81	0.85	0.79	0.78	0.89	0.82±0.0456
Fineness modulus(FM)	2.42	2.40	2.35	2.33	2.21	2.45	2.348±0.090
pH	7.2	8.39	8.31	8.22	8.42	8.44	8.36±0.0907
Electrical Conductivity, dS/m	-	1.91	1.86	1.82	1.95	1.93	1.89±0.0531

Average of three results; Bulk density results outside and in the parentheses are at loose state and rodded state respectively.

Table 3: Comparison of elemental composition of sand and CSFB.

Element	Sand[1]	CSFB					Average
		S1	S2	S3	S4	S5	
Silica as SiO_2, %	90-95	58.2	57.1	56.7	56.9	58.9	57.6±0.947
Iron as Fe_2O_3, %	2.68-8.25	2.41	2.32	2.59	2.4	2.38	2.42±0.101
Aluminum as Al_2O_3, %	0.005-0.01	34.2	34.9	33.7	33.9	34.6	34.3±0.492
Calcium as CaO, %	0.9-1.8	2.48	2.56	2.41	2.46	2.76	2.53±0.137
Magnesium as MgO, %	0.02-07	0.95	0.98	0.91	0.93	0.92	0.94±0.027
Sodium as Na_2O, %	0.01-0.4	0.72	0.74	0.69	0.75	0.79	0.74±0.037
Potassium as K_2O, %	0.01-01	0.25	0.21	0.22	0.19	0.28	0.23±0.035

Based on single analysis; 1= from the literature

Table 4: Particle size distributions for sand and CSFB samples.

IS sieve size, mm	Sand	Percent fines CSFB				
		S1	S2	S3	S4	S5
10	100	100	100	100	100	100
4.75	100	100	100	100	100	100
2.36	94.5	92	94	91	94	96
1.18	82.4	79	82	78	84	80
0.60	61	61	60	65	62	58
0.30	11.2	13	11	12	13	10
0.15	1.5	1.5	1.4	1.7	1.6	1.2

in CSFB, the durability and strength could be achieved. In addition to the above, the concrete produced from the partial replacement by CSFB could exhibit substantial enhancement in thermal melting and thermal performance, because of the presence of mullite binding phase mineral in the fire bricks (i.e., by XRD analysis in many refractory fire bricks, Nasr et al.1982). This was also evidenced from the recent investigation (Al-Amaireh 2006). However, further investigations are necessary to understand the micro mechanism of ettingette formation, durability and strength aspects, and extent of replacement level, thermal performance, and others.

Fig. 4: Particle size distribution for sand.

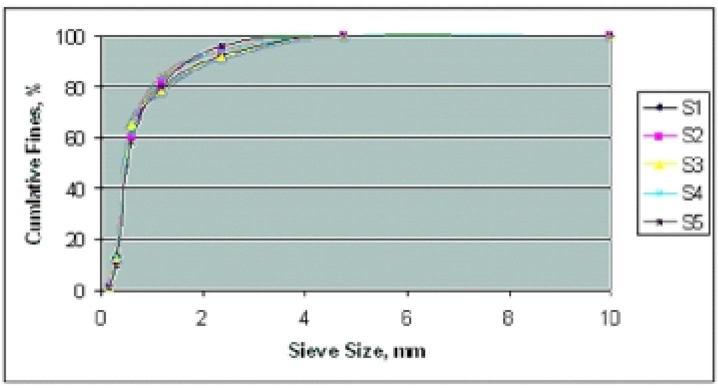

Fig. 5: Particle size distribution for CSFB samples.

CONCLUSIONS

The SFB is a locally available, low cost, and inert industrial solid waste whose disposal is a matter of concern like construction waste. On an overall, the CSFB can be comparable to the natural river sand. The CSFB satisfies the zone II gradation for not only to partially replace the sand, but for making good concrete. The CSFB seems to posses pozzolanic properties, as it contains silica, alumina, and little calcium. The SFB may aid in enhancing the bench-marked thermal performance of concretes.

FUTURE RESEARCH

The research carried out so far is only in the initial stage of this project. Strength and durability studies have not been done on concrete containing CSFB. Therefore, it is planned that strength properties like compressive strength, split tensile strength, flexural strength and impact strength, and durability properties like alkali-silica reaction, freeze-thaw, chloride ion permeability, interaction with air-entraining agents, fatigue strength, etc. of concrete made with CSFB will be studied.

REFERENCES

Al-Amaireh, M. J. 2006. Improving the Physical and Thermal Properties of the Fire Clay Refractory Bricks Produced from Bauxite. Appl. Sci., 6(12): 2605-2610.

Nasr, I., Abdel Kader, F.M. and Embabi, H.K. 1982. Improving the refractory quality of bauxite refectories. Ber. of Kerm. Qes., 59: 232-241.

IS 6-1967. Specification for Moderate Heat Duty Fire Clay Refractories. Bureau of Indian Standards, New Delhi.

IS 8-1967. Specification for High Heat Duty Fire Clay Refractories (3 Copies). Bureau of Indian Standards, New Delhi.

IS 8-1983. Specification for High Heat Duty Fire Clay Refractories. Bureau of Indian Standards, New Delhi.

IS 383-1970. Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi.

IS 456-2000. Code of Practice for Plain and Reinforced Concrete. Bureau of Indian Standards, New Delhi.

IS 389-1963. Coarse and Fine Aggregate from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi.