Utilization of Brine Sludge in Manufacturing of Bricks Manufacturing of Fly Ash Bricks

[1]Maaz Allah Khan, [2]Vipin Kumar Yadav, [3]Suryansh Singh, [4]Akash Singh Yadav, [5]Upendra Sharan

[1]Assistant Professor, [2]Student, [3]Student, [4]Student, [5]Student
Department of Civil Engineering,
Dr. Shakuntala Misra National Rehabilitation University, Lucknow
Lucknow, Uttar Pradesh, India

***Abstract*: The Indian automotive industry has emerged as a 'sunrise sector' in the Indian economy with an annual production of 23.37 million vehicles in 2014-15. Even it is a value adding industry, it has several environmental impacts causing land and water pollution with toxicity. Effluent sludge waste management becomes a big problem nowadays .Except engineered landfills, rest of the methods for dumping, leads ground water contamination and thereby other socio-economic impacts. Many studies have been conducted in this area and reported that the pollution level is high in ground water and nuisance due to dumping in the treatment plant area premises. There is a growing need to find alternative solutions for the sludge management. In the present study, an attempt has been made to utilize the automotive ETP sludge (dry) in making of construction materials, which is produced from TATA MOTARS, PUNE. Even to analyses the sludge, have been studied. For inducing strength materials like fly ash, lime, sand, cement, CaCl2, have been used. Sludge bricks show better compressive strength when compared with normal fly bricks or building bricks. Brine sludge is an industrial waste generated in chloral alkali industry. The generated brine sludge waste is dumped into landfills and contains barium Sulphate, calcium carbonate, magnesium hydroxide, Sodium chloride, clay, and toxic elements like chromium, zinc, copper, and Vanadium, therefore posing an environmental threat. Consequently, there is an urgent need to convert toxic brine sludge waste into its non-toxic form. The present invention thus aims to achieve total utilization of this brine sludge for making functionalized brine sludge material useful for a broad application spectrum.**

Index Terms: Industrial Waste, Recycling, Waste Management

INTRODUCTION

The rapid growth of industrialization in India in the recent years is the striking feature of nation's economic development. But the other side of industrialization has been the serious damage to the surrounding environment due to the wastes and pollutants generated from the industries. Various chemical, mining, steel, fertilizer, paper, and pulp industries generate huge amounts of wastes out of their production processes. The uncontrolled dumping of these wastes causes irreparable damage to the surface and ground water, air, and soil and has become a matter of serious concern for the protection of environment. Thus, the utilization/recycling of these waste materials are quite desirable for the sustainable development of the economy and for ensuring a clean and safe environment. Attempts have been made earlier to utilize various industrial wastes as an alternative material in the construction industry. Balasubramanian et al. [1] have suggested that the use of textile ETP sludge up to a maximum of 30% substitution for cement may be possible in the manufacture of nonstructural building materials. Several researchers reported that the slag obtained from different sources can be utilized as a supplementary raw material in different construction applications [2–5].Saxena et al. [6] investigated the use of copper tailings up to 50% in replacement of clay in the manufacture of bricks. Saikia et al. [7, 8] reported that the hydration characteristics of metakaolin-lime system are enhanced by coalmining kaolin with petroleum ETP sludge and the properties of blended cement are improved by replacing 20% cement with cocalcined kaolin-sludge containing up to 30% sludge. The brine sludge, a waste of chlor-alkali manufacturing industry, is generated during the chlorine and caustic soda production through the electrolysis of brine. There are about 40 units manufacturing caustic soda in India with an installed capacity of 2.27 million tons per annum [9]. The major environmental problems and challenges posed by this industrial sector are related to the disposal of brine sludge which may contain hazardous or toxic materials that precipitate from the brine. Even when the sludge produced is nonhazardous, it may contain substantial levels of dissolved metals and other impurities which during the course of time get leached out, thereby affecting ecosystem. It is, therefore, required to find alternate solutions for brine sludge management to render it suitable for ecologically safe disposal by stabilizing leachable impurities. The use of Portland cement or blended systems for treatment of heavy metals bearing liquids, sludges, and particulate wastes is well established [10, 11]. A US patent [12] provided the process for using silica-rich geothermal brine sludge to make a concrete material. In US Patent no. 4,113,504 issued to Chen et al., the heavy metals of brine sludge produced frommercurycathode brine electrolysis cell operation were fixed using vermiculite and cement. Styron, US Patent no. 4,226,630, discloses that fly ash may be added to increase the strength of concrete. Fly ash is a fine particulate residue obtained as a by-product of combustion of pulverized coal in thermal power plants. Presently, over 120 million tons of fly ash is generated in India. Fly ash, by far, is the most researched pozzolana used in the stabilization process of waste materials. The solidification/stabilization (S/S) has been shown by many studies to be a viable treatment processor reducing or immobilizing the contaminants in wastes by means of additives like cement, fly ash, or lime. Fly ash is an effective filler and adsorbent which has successfully replaced a portion of Portland cement in several S/S applications [13]. The combination of Portland cement and coal fly ash appears to optimize the S/S process and trap metals into the matrix (by forming a less permeable solid) better than what purely cement or pozzolanic materials do [14]. So far, to the best of our knowledge, the utilization of brine sludge in construction materials has not been reported in the recent literature. Taking into account all the above-mentioned factors, the objective of the present investigation is to study the effect of incorporation of brine sludge in Portland cement fly ash formulations and to provide a novel composition to develop precast concrete paver blocks and bricks by utilizing brine sludge. The effect of brine sludge concentration on the engineering properties of brine sludge-fly ash-Portland cement binders, paver blocks, and bricks is discussed in the paper. The leach ability studies of the solidified product are also presented (See Table).

Metal ion	Concentration of metal ions determined by ICP-OES (mg/L)	IS 10500-2012 discharge limit of metal ions at inland surface water (mg/L)
Vanadium	0.12	0.2
Zinc	1.72	5.0
Copper	2.03	3.0
Iron	3.20	3.0

Table1: Leachability studies

MATERIAL & METHODS

Raw Materials

Brine Sludge. The sample of brine sludge procured from Dahej, Gujarat, was dried at 100 ± 2∘C for 48 hrs, cooled to ambient temperature, and analyzed for various chemical constituents by X-ray fluorescence (XRF) spectroscopy (model: S8, make: Bruker, German) and as per the test procedures prescribed in the standard [15]. The results of physical and chemical analysis of sludge are given in Table 1. The sludge was alkaline in character as indicated by its pH and was ground in a ballmill to a fineness of 85% passing through 150 micron IS sieve.

Fly Ash. The fly ash sample (procured from Dahej, Gujarat) was evaluated for chemical composition by XRF .The mineralogical behavior of fly ash was accomplished using Xray diffraction technique (XRD, Rigaku D-Max 2200). The results of XRF analysis (Table 1) show that fly ash mainly consists of SiO2 (62.51%) and Al2O3 + Fe2O3 (26.88%), together with secondary amounts of CaO, SO3, and MgO. This indicates that the fly ash used in this study is Type F (according to IS 3812-2003) [16]. The lime reactivity of fly ash determined as per standard test procedure mentioned in IS 1727 [17]was found to be 4.5N/mm2.The sample was ground in a ball mill to a fineness of specific surface area of 310m2/kg. The mineralogical characterization of fly ash (Figure 1) shows the presence of quartz as major crystalline phase along with small quantity of mullet, hematite, and magnetite. **Cement**. Ordinary Portland cement (OPC) of chemical composition (%) SiO2: 23.4, Al2O3: 3.39, Fe2O3: 4.2, CaO: 63.42, MgO: 3.21, SO3: 1.8 and loss on ignition0.45%, physical properties specific gravity: 3.1, soundness: 1.5 mm, fineness: 330m2/kg blaine, setting time (minutes) initial: 155 and final: 213, and compressive strength: 28MPa (3 days), 39MPa (7days), and 49.5MPa (28 days) was used for this study. **Aggregates**: The physical and mechanical properties of fine aggregate (passing 4.75 micron IS sieve) and coarse aggregate (particles passing 10 micron IS sieve and retained over 4.75 micron IS sieve) tested as per IS 2386 [18] are presented in Table 2.

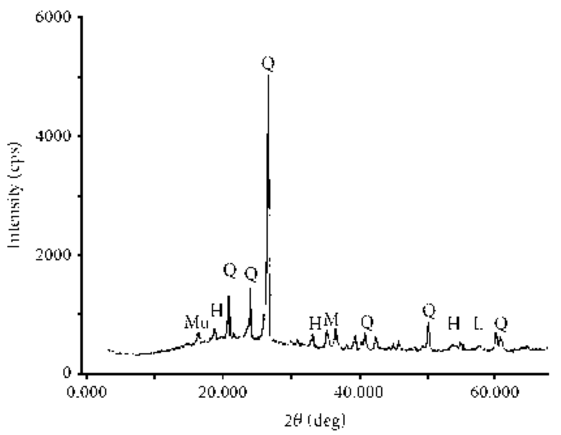

Table 2: Physical and chemical properties of coarse and fine natural aggregates

Property	Fine aggregate	Coarse aggregate
Fineness modulus	2.55	6.60
Bulk density, kg/L	2.55	6.60
Specific gravity	2.52	2.64
Impact value,%	-	14.2
Water absorption,%	0.25	22.3
Los Angeles abrasion resistance, %	-	22.5
Flakiness index,%	-	15.2

Physical Parameters

Property	Fine aggregate	Coarse aggregate
CaO	35.41	19.16
SiO2	41.90	51.32
Fe2O3	6.84	4.45
Al2O3	6.47	2.55
Others	2.09	22.52

Chemical Parameters

Preparation and Evaluation of Cement-Fly Ash-Brine Sludge Binders. The cement-fly ash-brine sludge binders were prepared by blending brine sludge with fly ash and Portland cement in different proportions. These compositions were designated as B1, B2, B3, B4, and B5 as shown in Table 3.Thereafter, the brine sludge binders were tested and evaluated for various physical properties. The initial and final setting time of the binders was determined using a Vicat apparatus as per the standard test procedure [10]. For the determination of compressive strength and water absorption of brine sludge binders, cubic specimens of size 50mm were cast at 33% consistency and cured under high humidity (>90%) at 27 ± 2∘C for different hydration periods up to 28 days. The compressive strength test was done in accordance with the standard procedure [19] after drying the specimens of respective hydration periods at 42 ± 2∘C for 2 days. The average value of 4 specimens is reported. The soundness of binder samples was tested by Le Chatelier clamp expansion test as per the method described in IS 6909-2004 [20]. The bulk density, water absorption, and porosity were tested according to methods prescribed in the literature [21].

RESULT & DISCUSSION

Properties of Cement-Fly Ash-Brine Sludge Binders. The determination of compressive strength provides a measure of the binding strength of cement to the waste (brine sludge and fly ash) and is one of the important indices to evaluate the quality of the solidified product for application in construction materials. The measured 3-day, 7-day, 14-day, and 28-day compressive strength and other properties of the cement-fly ash-brine sludge binders are summarized in Table 6. From the test results, it can be observed that the properties of binders are affected by the cement/fly ash/sludge ratios. The mix composition B2 has comparatively lower values of setting time and soundness than the mix compositions B1, B3, B4, and B5. Data shows that the compressive strength increased with the increase in hydration period in all compositions and maximum strength was achieved for the mix composition B2. It is also observed that the compressive strength of binder specimens decreased with an increase in the concentration of brine sludge at same curing age .The phenomenon is even more adverse when the sludge content in specimens is 50% or beyond it. For instance, the compressive strengths of B2 binder are 14.5%, 6.8%, 34.6%, and 51.2% higher than B1, B3, B4, and B5 binders, respectively, at the age of 28 days. The enhancement in the strength of binders with curing period is due to the hydration of Portland cement and the pozzolanicreaction of fly ash. The high proportions of silica, alumina, and iron oxide in cement and the reaction of meta stable silicate present in fly ash with Ca2+ ions lead to the formation of calcium silicates and aluminates which bind the entire mass together producing a solidified matrix. Also the high pH in the matrix results in the precipitation of metal ions as metal hydroxides (stabilization). The cement matrix encapsulates these hydroxides and makes them immobile (solidification). This imparts both chemical stability and physical solidity to the treated waste. Moreover, the incorporation of fine fly ash particles into the binders proves to be favorable in many ways. The fly ash particles fill into the internal voids and capillary channel to decrease the number of large pores in the matrix. They also adsorb metal ions on their surface. These phenomena of filling and adsorption are function of the percentages of the fly ash used, such that the more the fly ash particles are added, the more effective their rolebe comes .Hence, the compressive strength of B3 binder is higher than that of B1 and further increases as the fly ash content increases (B2 binder) at all the ages.

Water Absorption and Porosity of Cement-Fly Ash-Brine Sludge Binders. The water absorption and porosity are key factors for estimation of strength and durability of the binders. The specimens of mix compositions B1, B2, B3, B4, and B5 cured for 28 days were dried at 42 ± 2∘C and then immersed in water to measure their water absorption and porosity after different immersion periods.

The temperature of the water was maintained at 25 ± 2∘C. The effect of immersion in water on the water absorption and porosity of binders B1–B5 are shown in Figures 2 and 3, respectively. It can be seen from the figures that water absorption and porosity of all binders increased with an increase in the immersion period but became approximately linear after 7days of immersion in water and ranked in the flowing order: B5 > B4 > B1 > B3 > B2. These results clearly manifest the absence of leaching in all compositions which is ascribed to the filling up of pores in the binder matrix with the hydration products that make the binder particles integrate with each other.

Paver Blocks. The 28-day cured cement concrete paver blocks of M30 grade were tested for various physical properties as shown in Figure 4. It was observed that the compressive strength (C.S.) as well as flexural strength (F.S.) decreased and water absorption (W.A.) increased when the amount of brine sludge in the blocks increased from P2 to P4 as compared to the control mix P1. However, the properties of mix P2 and P3 conformed to the minimum limits of M30 grade paver blocks laid down in the standard [22]. On the other hand, mix P4 failed to pass the minimum strength criterion forM30 grade paver blocks. On the basis of properties of blocks and consideration for maximum utilization of brine sludge (35%),the mix composition P3 was optimized. These blocks can be used in building premises, public gardens/parks, and so forth.

Bricks. The properties of cement-fly ash-brine sludge bricks(size: 190 × 90 × 90 mm) incorporating 20, 25, and 30% brine sludge designated as R1, R2, and R3 are illustrated in Figure 5. The results show that the compressive strength (C.S.) of bricks decreased and water absorption increased (W.A.) with increase in the brine sludge concentration. The compressive strength of mix R3 is much lower than R1and R2 mixes and does not fulfill the minimum strength requirement of class 5 bricks specified in IS 12894 . A slight enhancement in the bulk density (B.D) of bricks was observed with increased proportion of brine sludge. The drying shrinkage of the R1, R2, and R3 designated bricks tested as per the method described in IS 4139 [24] lied within the maximum specified value of 0.15 percent. The properties of the cement-fly ash-brine sludge bricks are comparable with the bricks prepared from fly ash-cement binder and other wastes. The photographs of paver blocks and bricks are shown in Figure

Paver Blocks

Fly ash Bricks

CONCLUSION

(1)The brine sludge can be utilized for making construction materials in cement-fly ash-brine sludge binder, concrete paving blocks, and bricks.

(2) The compressive strength increased with the increase in hydration period in all compositions and maximum strength was achieved for the mix composition B2 comprised of 20% sludge, 30% fly ash, and 50% cement.

(3) The fine particles of fly ash play an important role in filling pores and internal gaps in the matrix to generate a compact structure with reduced water absorption and porosity.

(4) The properties of paver blocks and bricks complied with the requirement of Indian standards. The results show that brine sludge up to 25 and 35% can be utilized for making paver blocks and bricks, respectively.

(5) The hydration products, that is, calcium silicates and aluminates, bind the entire mass together producing a solidified matrix and immobilize the dissolved metal ions into it by their consequent adsorption and precipitation.

(6) The leach ability studies confirm that the metals and impurities in the sludge are substantially fixed in the solidified product.

(7) The utilization of brine sludge in construction materials enables the disposal of large amounts of sludge while consuming lesser amounts of cementing materials than heretofore possible.

REFERENCES

[1] J. Balasubramanian, P. C. Sabumon, J. U. Lazar, and R. Ilangovan, “Reuse of textile effluent treatment plant sludge in building materials,”Waste Management, vol. 26, no. 1, pp. 22–28, 2006. Journal ofWaste Management 7

[2] Y. Xue, S. Wu,H.Hou, and J. Zha, “Experimental investigation of basic oxygen furnace slag used as aggregate in asphalt mixture,” Journal of Hazardous Materials, vol. 138, no. 2,pp. 261– 268, 2006.

[3] P. Ahmedzade and B. Sengoz, “Evaluation of steel slag coarse aggregate in hot mix asphalt concrete,” Journal of Hazardous Materials, vol. 165, no. 1–3, pp. 300–305, 2009.

[4] M. Maslehuddin, A. M. Sharif, M. Shameem, M. Ibrahim, and M. S. Barry, “Comparison of properties of steel slag and crushed limestone aggregate concretes,” Construction and Building Materials, vol. 17, no. 2, pp. 105–112, 2003.

[5] W. Shen,M. Zhou, W. Ma, J. Hu, and Z. Cai, “Investigation on the application of steel slag-fly ash-phosphogypsum solidified material as road base material,” Journal of Hazardous Materials, vol. 164, no. 1, pp. 99–104, 2009.

[6] M. Saxena, V. SornaGowri, J. Prabhakar, and T. Sangeetha, “Innovative building materials: polymer composites, copper tailing bricks, and blue dust primers,” Civil Engineering & Construction Review, vol. 15, pp. 46–50, 2002.

[7] N. J. Saikia, P. Sengupta, P. K. Gogoi, and P. C. Borthakur, “Cementations properties of metakaolin-normal Portland cement mixture in the presence of petroleum effluent treatment plant sludge,” Cement and Concrete Research, vol. 32, no. 11, pp. 1717–1724, 2002.

[8] N. J. Saikia, P. Sengupta, P. K. Gogoi, and P. C. Borthakur, “Hydration behaviour of lime-co-calcined kaolin-petroleum effluent treatment plant sludge,” Cement and Concrete Research, vol. 32, no. 2, pp. 297–302, 2002.

[9] “CPCB Report on ‘Review of Environmental standards of Caustic Soda industry (Membrane cell) and preparation of COINDS on Caustic soda’,” 2013.

[10] F. P. Glasser, “Fundamental aspects of cement solidification and stabilisation,” Journal of Hazardous Materials, vol. 52, no. 2-3, pp. 151–170, 1997.