JIPC - P -105

Jr. of Industrial Pollution Control 27(1)(2011) pp 33-38

UTILIZATION OF INDUSTRIAL EFFLUENT TREATMENT PLANT (ETP) SLUDGE AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

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Key words : ETP sludge, Lime sludge, Use of ETP sludge in concrete, Supplementary cement,

ABSTRACT

A systematic study was undertaken to utilize industrial effluent treatment plant (ETP) sludge as partial replacement for cement in M20 concrete. The ETP sludges selected for this study are those generated by lime treatment of automobile, engineering and lead battery industry effluents. The cement in the concrete mix was replaced by 5, 10 and 15 weight percentage of ETP sludges and concrete blocks (10cm x 10cm x 10cm) were prepared. The concrete blocks were subjected to unconfined compressive strength (UCS) at different curing days (7, 14, 21 and 28 days) to assess the strength. The highest UCS value was obtained in all the three cases studied by replacing cement with 5% sludge after 28 days curing. With this optimum sludge content of 5 weight %, the UCS value of concrete were 47.6 N/mm^2, 52.9 N/mm^2 and 49.8 N/mm^2 for automobile ETP sludge, engineering ETP sludge and lead battery sludge respectively as against 50.4 N/mm^2 for the control without sludge.

INTRODUCTION

The technological development led to rapid industrialization which is always associated with the problem of environmental degradation. With the advent of pollution control technologies, the industries are able to combat air and water pollution. However, the treatment of industrial effluents invariably results in the generation of large volume of the sludge transferring pollutants from liquid phase to solid phase. The indiscriminate disposal of the sludge from effluent treatment plants (ETP) deteriorate surface soil and contaminate ground and surface water, which become an important environmental and public health issue. Considering the seriousness of the same, the Ministry of Environment and Forests (MoEF), Government of India, listed chemical sludge from wastewater treatment as hazardous waste (MoEF 2008). Under the guidelines for Management and Handling of hazardous wastes, land fill disposal is recommended for inorganic sludge from wastewater treatment plants (MoEF, 1991).

Besides collection, transport and storage of wastes, construction of secured land fill sites pose problems of land acquisition, high land and construction cost, closure of site, environmental monitoring etc. Therefore, it is now a global concern to find a socio, techno-economic and ecofriendly solution to dispose industrial solid wastes. The recycling of industrial solid wastes as substitute for building materials is not only environment friendly but also cost effective alternative way to sustain a cleaner and greener envi-

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ronment. The usage of sand, stone, gravel, lime, clay, gypsum, etc as building materials and manufacture of other building materials such as brick, cement, etc. depletes the existing natural resources and damage the environment due to continuous exploitation. Nevertheless, the manufacture of these building materials emits gaseous pollutants which are well known for its ill effects towards global warming. It is reported that the production of one tonne of portland cement emits one tonne of carbon dioxide to the atmosphere (Senthil Kumaran *et al.* 2008). Hence the usage of industrial solid wastes as building materials will exhibit environmental benefits such as conservation of natural resources/raw materials, decrease mining activity, reduce landfill capacity, minimize global warming.

Considering the environmental concern, the use of industrial solid wastes, especially, use of ETP sludge as a partial supplement to building materials plays an important role and it is gaining a great momentum. The exhaustive review on the utilization of hazardous wastes and by-products as a supplementary green concrete material concluded that the partial substitution of solid hazardous wastes in the place of conventional construction materials such as gravel, sand, blue metal, etc do not strongly affect the strength of concrete and other properties (Smita Badur and Rubina Chaudhary, 2008). Balasubramanian et al (2006) examined the potential use of textile ETP sludge in building materials and concluded that the substitution of textile ETP sludge for cement upto a maximum of 30 percent, may be possible in the manufacture of non-structural building materials. Anupam Singhal *et al.* (2008) substituted cement with lime treated spent pickling liquor sludge (7.5 percent by weight) and fly ash (15 percent by weight) in M 20 concrete and found that the concrete thus prepared gave optimum compressive strength and effected complete removal of toxicity. Chin-Haung Weng et al (2008) manufactured bricks from dried sludge collected from an industrial wastewater treatment plant. The study concluded that the condition for manufacturing good quality bricks is 10 weight percent sludge with 24 percent moisture content prepared in the molded mixtures and fixed at 880-960^{o}C. Besides ETP sludge, utilization of copper slag (Pereira Gonclaves *et al*. 2007), ground granulated blast furnace slag (Swaroopa Rani *et al.* 2009) and municipal solid waste incineration ash (Pai-Haung Shih, 2003) as a partial replacement of cement in concrete is already reported in the literature.

MATERIALS AND METHODS

ETP sludges tested for this study were collected from automobile, engineering and lead acid battery industries. In the automobile industry, the effluent is mainly generated from degreasing, phosphating and painting operations. In the case of engineering industry, the effluent is generated from pickling, degreasing and phosphating operations. On the other hand, the washings from pastings, formation and plate parting form the major sources of effluent from lead acid battery industry. In all the three cases, the effluent is invariably treated with lime slurry to precipitate heavy metals such as zinc and lead as hydroxides and also neutralisation of residual hydrochloric acid as calcium chloride in the case of engineering industry and sulphuric acid as calcium sulphate (gypsum) in the case of lead battery industry. The sludge samples were analysed as per the standard methods (APHA, 2005) and the results are presented in Table 1.

Table 1. Characteristics of automobile ,engineering sludge and lead acid battery ETP sludge

Parameters	Automobile ETP sludge	Engineering ETP sludge	Lead acid battery
ETP sludge			
pH (50% solution)	9.24	9.02	9.34
Total solids (%)	97.2	92.0	98.0
Total volatile solids (%)	15.7	11.0	12.5
Moisture content (%)	2.8	8.0	2.0
Calcium (as Ca) (mg / kg)	1,64,400	12,620	79,200
Magnesium (as Mg) (mg / kg)	7,466	4,950	32,340
Sodium (as Na) (mg / kg)	1,500	5,800	1,100
Pottassium (as K) (mg / kg)	200	700	300
Zinc (as Zn) (mg / kg)	2,481	1,373	728
Iron (as Fe) (mg / kg)	6,400	19,750	4,200
Lead (as Pb) (mg / kg)	172	104	522

The concrete cube test specimens tested of 10cm^3 (10cm x 10cm x 10cm) were prepared using cast iron moulds. The cement (make: L & T, portland pozzolana cement, fly ash base), coarse aggregate (20 mm graded) and fine aggregate (coarse sand) were mixed in the required proportions to obtain M-20 grate concrete. The concrete mix proportion adopted was 1: 1.62: 3.40 (cement: sand: coarse aggregate) with water to cement ratio was 0.5. The concrete blocks are prepared by hand mixing and cured in clean water as per the procedure given in IS: 516-2004. As a control sample, the concrete cube specimen of the same size was prepared without the addition of ETP sludge. On the other hand, the test samples were prepared by replacing cement portion only with by 5, 10 and 15 weight percent of the respective ETP sludge sample without any change of other ingredients. The samples particulars are presented in Table. 2. The specimens were subjected to unconfined compressive strength (UCS) after at 7 days, 14 days, 21 days and 28 days of curing. In this test, the concrete cube is kept in a compression testing machine and load is applied one after another. The ultimate load at which the specimen breaks gives the unconfined compressive strength and is measured in load per unit area.

Table 2. Details of specimens

Specimen No.	Cement %	Sludge %
Control (So)	100	0
Automobile ETP sludge		
SA_1	95	5
SA_2	90	10
SA_3	85	15
Engineering ETP sludge		
SE_1	95	5
SE_2	90	10
SE_3	85	15
Lead battery ETP sludge		
SL_1	95	5
SL_2	90	10
SL_3	85	15

RESULTS AND DISCUSSION

The UCS test results for specimens prepared with automobile industry ETP sludge is given in Table 3. The test results of specimens prepared with engineering industry sludge are presented in Table 4 and the results of specimens prepared with lead acid battery industry sludge are given in Table 5. A comparison of UCS values of specimens containing 5 weight percent of each ETP sludge with control specimen without sludge is shown in Table 6. The results are also shown in Figures 1 - 3 separately for each ETP sludge and the comparison of results is depicted in Figure 4.

The results reveal that there is a uniform decrease in UCS values with increase of sludge content in all the three cases. As expected, the strength increases as the curing time of concrete increases. In all three cases the highest UCS value is observed for 5 weight percent sludge addition and a curing time of 28 days. At the optimum content of 5 weight percent sludge,

Table 3. UCS test results for specimens prepared with different weight % of automobile ETP sludge

Sample No.	Sludge content(%)	UCS (N/mm^2) values at different curing days			
		7th day	14th day	21st day	28th day
S_o	0	27.6	37.0	43.6	50.4
SA_1	5	22.7	30.6	42.7	47.6
SA_2	10	22.5	28.5	34.5	46.8
SA_3	15	21.5	25.0	30.8	36.6

Table 4. UCS test results for specimens prepared with different weight % of engineering ETP Sludge

Sample No.	Sludge content(%)	UCS (N / mm^2) values at different curing days			
		7th day	14th day	21st day	28th day
So	0	27.6	37.0	43.6	50.4
SE_1	5	29.6	35.2	46.0	52.9
SE_2	10	30.7	32.3	39.1	48.5
SE_3	15	23.4	28.1	37.7	40.8

Table 5. UCS test results for specimens prepared with different weight% of lead acid battery ETP Sludge

Sample No.	Sludge content(%)	UCS (N / mm²) values at different curing days			
		7th day	14th day	21st day	28th day
S_o	0	27.6	37.0	43.6	50.4
SL_1	5	24.2	35.2	40.7	49.8
SL_2	10	22.2	26.1	39.6	46.5
SL_3	15	22.3	24.1	33.6	38.7

Table 6. Comparison of UCS test results for specimens prepared with different 5 weight % of each sludge

Sample No.	Sludge content(%)	UCS (N/mm²) values at different curing days			
		7th day	14th day	21st day	28th day
S_o	0	27.6	37.0	43.6	50.4
SA_1	5	22.7	30.6	42.7	47.6
SE_1	5	29.6	35.2	46.0	52.9
SL_1	5	24.2	35.2	40.7	49.8

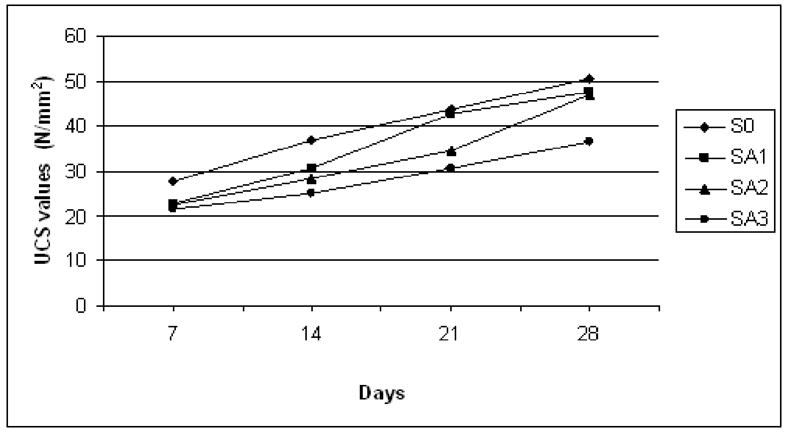

Fig. 1 UCS test results of concrete with and without automobile ETP sludge

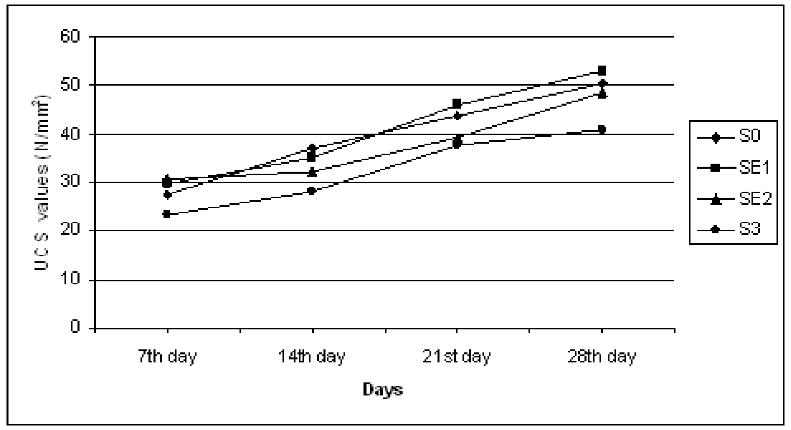

Fig. 2 UCS test results of concrete with and without engineering ETP sludge

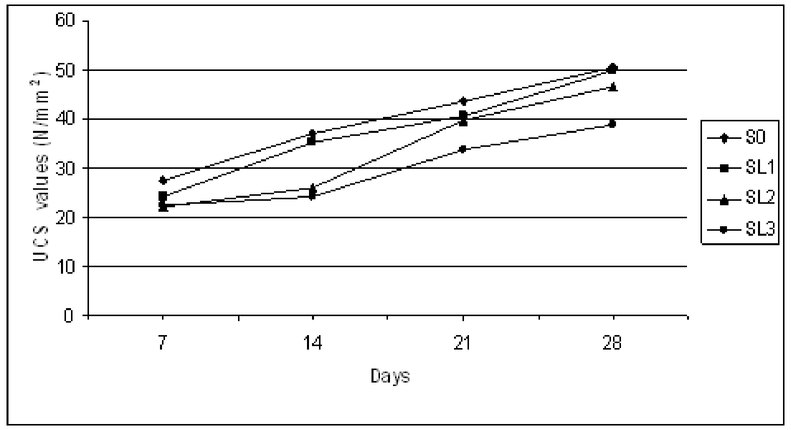

Fig. 3 UCS test results of concrete with and without lead acid battery ETP sludge

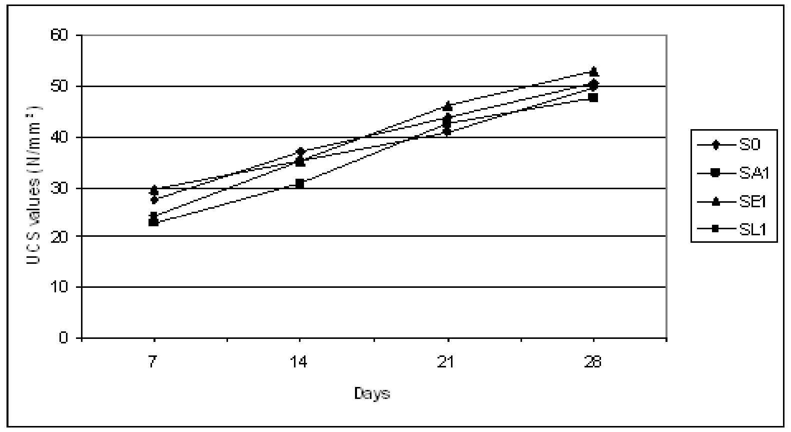

Fig. 4 UCS test results of concrete with and without various ETP sludges

the UCS value is found to be 47.6N/mm² and 49.8N/mm² for automobile ETP sludge and lead battery ETP sludge respectively, as against 50.4/mm2 for the control sample without sludge addition. The UCS value is decreased by 5.55 percent for automobile ETP sludge and the decrease is only marginal (1.19 %) for lead acid battery ETP sludge. On the other hand, the UCS value is 52.9N/mm² for engineering ETP sludge, which is about 4.96 % higher than the sample without sludge (control specimen).

Since the content of ETP sludge is complex in nature, the reason for increase or decrease in UCS value cannot be exactly explained with these data. It needs still in depth study about the composition of sludge and its interaction with cement and other additives. However, the reason for reduction of UCS value of 5.55 percent in the case of automobile sludge may be attributed to the presence of waste paint particles, which may coagulate and accumulate in the sludge. The organic nature of sludge due to paint waste may hinder the concrete formation and results in comparatively lower the UCS value. On the other hand, the marginal decrease in UCS value to the extent of 1.19 percent in the case of lead acid battery sludge may be due to the presence of calcium sulphate (gypsum) present in the sludge. The iron oxide present in the dry sludge of engineering industry may increase the UCS value to the extent of 4.96 percent.

CONCLUSION

The study concluded that partial replacement of cement in concrete with ETP sludge generated by lime treatment is suitable as building material. The study indicated that the replacement of cement with 5 percent automobile ETP sludge resulted in 94.4 percent of pure concrete strength and 98.8 percent in the case of lead acid battery ETP sludge. On the other hand, the concrete strength is increased by 4.96 percent by replacing cement with 5 percent of engineering ETP sludge. The study on durability and leachability of concrete prepared with ETP sludges is in progress. Based on the complete study results, the applicability of ETP sludges as partial replacement of cement in concrete either for structural or non-structural applications will be arrived.

REFERENCES

Anupam Singhal, Tewari,V.K. and Satya Prakash, 2008. Utilization of treated spent liquor sludge with fly ash in cement and concrete. *Building and Environment*. 43 (6) : 991-998.

Balasubramanian,J., Sabumon,P.C., John U. Lazar and Elangovan, R. 2006. Reuse of textile effluent treatment plant sludge in building materials. *Waste Management*. 26 (1) : 22-28.

Chih-Haung Weng, Deng-Fong Lin and Pen-Chi-Chiang, 2008. Utilization of sludge as brick materials. *Advances in Environmental Research*. 7 (3) : 679-685.

Indian Standard methods of tests for strength of concrete, Reaffirmed 2004. IS : 516-1959.

Ministry of Environment and Forests, Hazardous substances management division, Government of India, New Delhi 1991. *Guidelines for Management and Handling of Hazardous Wastes*. 63-64.

Ministry of Environment and Forests, Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.

Pai - Haung Shih, Juu-En Chang and Li-Choung Chiang, 2003. Replacement of raw mix in cement production by municipal solid waste incineration ash. *Cement and Concrete Research*. 33 (11) : 1831-1836.

Senthil Kumaran, G., Nurdin Mushule and Lakshmipathy, M. 2008. A review on construction technology that enables environmental protection - rubberized concrete. *American J. of Engineering and Environmental Technology*. 1 (1) : 40-44.

Smita Badur and Rubina Chaudhary, 2008. Utilization of hazardous wastes and by-products as a green concrete material through s/s process: A Review. *Adv. Mater. Sci*. 17 : 42-61.

Swaroopa Rani, M., Seshagiri Rao, M.V. and Shobba, M. 2009. Utilization of solid waste materials in self compacting concrete. *Environmental Pollution Control Journal*. 13 (1) : 44-47.

Washington Almedia Moura, Jardel Pereira Gonclaves and Monica Batista Leite Lima, 2007. Copper slag waste as a supplementary cementing material to concrete. *Journal of Material Science*. 42 (7) : 2226-2230.