International Journal of Mechanical Engineering

Large-Scale Utilization of Waste Foundry Sand in Geotechnical Applications as Flyash Stabilized Pavement Sub-Base

P. Senthil Kumar
Department of Civil Engineering, PSG College of Technology, Coimbatore - 641 004, Tamilnadu, India.

S. Gunaseelan
Department of Civil Engineering, PSG College of Technology, Coimbatore - 641 004, Tamilnadu, India.

Abstract

Foundry sand is an industrial by-product from the ferrous and non ferrous metal casting foundry industry. India being the second largest country producing various grades of metal castings, discards huge volumes of foundry sand every year, which requires an alternative for land filling to dispose. In an effort to utilize foundry sand in very high volume, the present study is carried out for its possible large-scale utilization in geotechnical applications as sub-base material for roads. Six samples of green foundry sand representing the various foundry industries in the Coimbatore cluster were collected and its geotechnical properties were determined. CBR tests conducted on these samples shows that many samples can be used directly for sub-base as per IRC standards. However, in order to make use of the all remaining samples, the foundry sand is stabilized with flyash for improving its CBR strength. This study shows the possibility of utilizing all the foundry sand samples as sub-base material for pavements satisfying IRC requirements with the addition of flyash.

Keywords: foundry sand, sub-base, flyash, light compaction test, CBR test.

INTRODUCTION

Through out the world, sieved high quality silica sand is used as a molding material in the ferrous and nonferrous metal casting industries for centuries. Due to cost of the material, foundries recycle and reuse the sand several times for different castings. When the sand can no longer be reused, it is discarded and removed from the foundry, which is generally termed as foundry sand.

In United States and Europe alone, approximately 21 million tons of foundry sand is discarded annually [1]. Presently, only 32% of discarded foundry sand is reused in civil engineering construction [2], due to either scanty information available on its beneficial use or application of bulk quantity of material is limited in its construction work. India, globally, second largest producer of casting way behind China [3,4], needs to dispose of the foundry sand effectively apart from land filling. Hence, the present study aims to utilize the foundry sand in large-scale road construction as sub-base material.

In India, roads are mostly designed as flexible pavement based on the IRC: 37-2001 guidelines. Though various methods are available for the flexible pavement design, the Indian Roads Congress (IRC) recommends the California Bearing Ratio method [5]. As per IRC 37-2001 standards, the CBR value of any sub-base materials should not be less than 20%. Therefore, the objective of this study is to investigate the suitability of the foundry sand, directly as sub-base material, based on the IRC 37-2001 recommended CBR value. Further, if any foundry sand material falls short of this mark, in order to make it suitable, it is stabilized with flyash by varying proportion, till achieving the required CBR value of 20%.

MATERIALS AND METHODS

Foundry Sand

Generally the green sand and the chemically bonded sand are the two types of foundry sand mostly used in the molding process. Green sand, which makes up the largest percentage of these two, basically made up of silica sand (80-85%), bentonite clay (8-10%), coal (3.5-6%) and other minor ingredients such as flour, rice hulls and cereals. For the purpose of study, six green foundry sand samples representing various foundry industries were obtained in and around the Coimbatore region. Foundry sand (FS) sample were collected from Seetha Lakshmi Foundry, Sidco (FS-1); Sastha Foundry, Sidco (FS-2); PSG Foundry, Neelambur (FS-3); S & D Foundry, Sidco (FS-4); VK Foundry, Vilankurichi (FS-5); and Indo Shell, Sidco (FS-6). The geotechnical properties of the all the foundry sand samples are presented in Table-1, including index dry densities.

Table-1. Geotechnical properties of foundry sands

Properties	FS-1	FS-2	FS-3	FS-4	FS-5	FS-6
Specific gravity	2.51	2.65	2.61	2.63	2.70	2.50
Gravel (%)	0	5.15	0	12.78	0.57	0.36
Sand (%)	99.73	94.48	98.58	85.85	95.51	97.24
Fines (%)	0.27	0.37	1.42	1.37	3.92	2.40
D_{10} (mm)	0.14	0.30	0.16	0.18	0.15	0.08
D_{30} (mm)	0.18	0.48	0.23	0.40	0.24	0.13
D_{60} (mm)	0.26	1.00	0.35	1.20	0.33	0.19
Coefficient of uniformity (C_u)	1.86	3.33	2.19	6.67	2.20	2.38
Coefficient of curvature (C_c)	0.89	0.77	0.95	0.74	1.64	1.11
IS classification	SP	SP	SP	SP	SP	SP
Maximum dry density (g/cc)	1.56	1.50	1.58	1.74	1.54	1.54
Minimum dry density (g/cc)	1.16	1.35	1.40	1.34	1.51	1.45

All the samples are tested as non-plastic. Soil classification of the samples is reported as per IS:1498 [6]. It is classified as poorly graded sand (SP), with soil particles of one size is predominant or some intermediate size is missing, which limits the use of foundry sand in civil engineering work. The difference in values between maximum and minimum index densities of foundry sand shows the scope for land filling operations.

Flyash

An industrial waste Neyveli flyash produced in Neyveli thermal power station in Tamilnadu was used as an additive to improve the CBR strength of the foundry sand. Among the various additives used for stabilization, flyash is available in large quantity and also it needs to be effectively disposed, to protect the environment. India produces about 90 million tons of coal ash per year from thermal power station, of which only 13% is used as land filling and other construction works. The physical properties of flyash are given in Table-2.

Table-2. Properties of flyash

Property	Value
Specific gravity	1.98
Maximum dry density (g/cc)	1.10
Optimum moisture content (%)	19.0
Permeability (cm/sec)	$5X10^{-5}$
Cohesion	Nil

Experimental Methods

Light compaction tests were carried out to determine the optimum moisture content (OMC) and the maximum dry density (MDD) of all the samples as per IS: 2720 - Part VII [7]. CBR tests were conducted according to IS: 2720 – Part 16 [8], on the compacted specimens in the CBR mould, to obtain the CBR value. The specimens were prepared at their OMC and MDD, and soaked under water for four days before testing. The compaction characteristics of the foundry sand specimens and its CBR values are shown in Table-3. Comparison of maximum dry density results shows that compaction densities are higher than index densities for poorly graded sand (SP) [9].

Table-3. Results of light compaction tests and CBR tests of foundry sands

Properties	FS-1	FS-2	FS-3	FS-4	FS-5	FS-6
Maximum dry density (g/cc)	1.80	1.78	1.60	2.16	1.72	1.65
Optimum moisture content (%)	12.0	14.5	21.0	12.0	18.0	14.0
CBR at 2.5mm penetration (%)	28.5	20.4	18.6	11.9	15.6	4.3
CBR at 5.0mm penetration (%)	45.7	31.3	28.1	24.1	20.6	6.7
Soaked CBR value (%)	45.7	31.3	28.1	24.1	20.6	6.7

RESULTS AND DISCUSSION

From the results obtained in Table 3, it is found that all foundry sand samples, except FS-6, CBR value is not less than 20%, hence suitable for road sub-base material satisfying the IRC standards. In order to make use of remaining foundry sand sample (FS-6), it is stabilized with flyash, at an amount of 3%, 5% and 10% (by weight). The results of flyash stabilized foundry sand (FS-6) is shown in Table-4.

Table-4. Results of light compaction tests and CBR tests of flyash stabilized foundry sand (FS-6)

Property	Flyash (%)		
	3	5	10

Maximum dry density (g/cc)	1.57	1.58	1.59
Optimum moisture content (%)	15.6	20.0	21.7
CBR at 2.5mm penetration (%)	11.7	20.2	5.7
CBR at 5.0mm penetration (%)	14.1	26.9	7.6
Soaked CBR value (%)	14.1	26.9	7.6

The result from Table-4 shows that the addition of flyash acts as a filler, by increasing the CBR value and thereby it is possible to achieve the required CBR value of 20%, with 5% flyash addition.

CONCLUSION

Based on the present study, it is ensured that all the waste foundry sand can be effectively utilized as a successful sub-base material; thereby it is possible for large-scale application in road construction without any compromise and provides possible alternative for land filling.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the financial support for this study from Tamilnadu State Council for Science and Technology (TNSCST), Government of Tamilnadu, Chennai through the grant No.TNSCST/SPS/AR/2009-10/ECV-01.

REFERENCES

[1] IS: 1893(Part 1): 2016 “Criteria for Earthquake Resistant Design of Structures”, Part-1 General Provisions and Buildings, Fifth Revision, Bureau of Indian Standard, New Delhi, India.

[2] ALACI, Z. KALITCHIN, M. KANDEVA, F. CIORNEI: Method and Device for the Study of Damping of Environmental Friendly Foam Type Materials. In *J Environ Prot Ecol* **21**(4), 1298 (2020)

[3] SAP 2000 Manual (Version 14), “CSI Getting Started with SAP2000”, Computers And Structures, Inc. Berkeley, USA.

[4] JAGADALE S.H. AND SHELKE N.L.,2016, “Analysis of Various Thicknesses Of Shear Wall With Opening And Without Opening and Their Percentage Reinforcement”, International Journal of Research in Engineering, Science and Technologies, Vol. 1, pp. 212-218.

[5] BAGHERI B. et al., 2012, “Comparative Study of The Static and Dynamic Analysis of Multi-Storey Irregular Building”, International Scholarly and Scientific Research & Innovation, World Academy of Science, Engineering and Technology Vol:6.

[6] LAVANYA PRABHA, S., GOPALAKRISHNAN, M., NEELAMEGAM, M.: Development of high-strength nano-cementitious composites using copper slag, ACI Materials Journal, 2020, 117(4), pp. 37–46.

[7] MOHAN, A , VIJAYAN, D.S. , REVATHY, J., PARTHIBAN, D., VARATHARAJAN, R.: Evaluation of the impact of thermal performance on various building bricks and blocks: A review, Environmental Technology and Innovation, 2021, 23, 101577(2021)

[8] M. THOLKAPIYAN, A.MOHAN, VIJAYAN.D.S: A survey of recent studies on chlorophyll variation in Indian coastal waters, IOP Conf. Series: Materials Science and Engineering 993 (2020) 012041, 1-6.

[9] AJAY HIRAPARA, DHANANJAY PATEL, 2017, “Analysis Of Light Weight Formers In Concrete Slabs Using Voids” International Journal of Advance Engineering and Research Development (IJAERD) Volume 4, Issue 4.

[10] AWADH EWAYED AJEEL, TAMARA ADNAN QASEEM, SALWA RAHMAN RASHEED,2018, “Structural behavior of voided reinforced concrete beams under combined moments” Civil and Environmental Research Vol.10,No:1.

[11] GEE-CHEOL KIM, JOO-WON KANG, 2012, “Calculation of Voided Slabs Rigidities” International Journal of Civil and Environmental Engineering Vol:6, No:5.

[12] JOO-HONG CHUNG, HYUNG-SUK JUNG, BAEK-IL BAE, CHANG-SIK CHOI AND HYUN-KI CHOI, 2018, “Two-Way Flexural Behavior of Donut-Type Voided Slabs” International Journal of Concrete Structures and Materials.

[13] THAAR S. AL-GASHAM, ALI N. HILO, MANAL A. ALAWSI 2019,“Structural behavior of reinforced concrete one-way slabs voided by polystyrene balls” Case Studies in Construction Materials, Vol 11.

[14] GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S. (2020). Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In Journal of Environmental Protection and Ecology (Vol. 21, Issue 6, pp. 2153–2163).

[15] LAVANYA PRABHA, S., DATTATREYA, J.K., NEELAMEGAM, M., SESHAGIRI RAO, M.V., Investigation of bolted RPC plate under direct tension, Journal of Structural Engineering (Madras), 2009, 36(5), pp. 333–341

[16] MOHAN, A., TABISH HAYAT, M.: Characterization of mechanical properties by preferential supplant of cement with GGBS and silica fume in concrete, Materials Today: Proceedings, 2020, 43, pp. 1179–1189.

[17] DHARMAR, S., GOPALAKRISHNAN, R., MOHAN, A.: Environmental effect of denitrification of structural glass by coating TiO2, Materials Today: Proceedings, 2020, 45, pp. 6454–6458

[18] CHEONG,K.H.ANDLEE,S.C:“StrengthofRetempered Concrete”,ACIMaterialsJ.90(3),203-206 (1993)

[19] KIRUTHIKA, C., LAVANYA PRABHA, S., NEELAMEGAM, M.: Different aspects of polyester polymer concrete for sustainable construction Materials Today: Proceedings, 2020, 43, pp. 1622–1625

[20] PRABHA, S.L., SURENDAR, M., NEELAMEGAM, M.: Experimental investigation of eco-friendly mortar using industrial wastes ,Journal of Green Engineering, 2019, 9(4), pp. 626–637