Innovative Ideas for Manufacturing of the Green Concrete by Utilizing the Used Foundry Sand and Pozzocrete

Dushyant R. Bhimani, Jayeshkumar Pitroda, Jaydev J. Bhavsar

Abstract-Eco-efficient and low cost concrete can be produced by blending various ratios of fine aggregate and cement with used foundry sand and Pozzocrete. As a partial replacement of cement in concrete by Pozzocrete P60, which is a processed quality assured fly ash introduces many benefits from economy, technical and environment point of view. Metal casting process generate several kinds of waste, used foundry sand is the main waste. Used foundry sand is major problem for Indian Small and medium scale Foundry. Since used foundry sand make intensive use of sand as primary direct material, the regeneration of this sand can be considered as main factor in environmental performance to achieve sustainable development. This paper presents the results obtained of the concrete having mix proportion 1:1.48:3.21 in which cement is partially replaced by Pozzocrete P60 as 30% by weight of cement; and fine aggregate is partially replaced by used foundry sand obtained from ferrous and non-ferrous metal casting industries as 10%, 30% and 50% by weight of fine aggregate. For this study, five sets of mixture proportions were made. First (A0) were the standard mix containing no Pozzocrete and no used foundry sand, with regional fine aggregate and coarse aggregate. Second mix (C0) contained 30% Pozzocrete P60 as a replacement of cement. Other mixes (C1, C2 and C3) contained Pozzocrete P60 (30%) plus used foundry sand (10%, 30% and 50%) respectively. The compressive strength of each sample is carried out at 7, 14 and 28 days. The water absorption test is also carried out at 28 days. This research was performed to achieve technical, ecological and economic benefits by utilizing the huge amounts of used foundry sand and Pozzocrete, produced every year, in India and elsewhere.

Keywords: Pozzocrete P60, used Foundry Sand, Partial replacement, Concrete, Compressive strength, Fine aggregate, Cost.

I. INTRODUCTION

Concrete is a composite construction material, made by mixing of cement, aggregate (generally coarse aggregate made of gravels or crushed rocks such as limestone or granite, plus a fine aggregate such as sand), water and admixtures (if required)). The proportionate quantity of each material affects the properties of hardened concrete. Due to various environmental concerns and the need for energy conservation, various research works have been directed towards the utilization of various waste materials.

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Dushyant R. Bhimani, Student of final year M.E. C E & M, B.V.M. EngineeringCollege, VallabhVidyanagar

Jayeshkumar Pitroda, Assistant Professor & Research Scholar, Civil Engg Department, B.V.M. Engg. College, VallabhVidyanagar

Jaydev J. Bhavsar, Associate Professor,CivilEngg Department, B.V.M. Engg. College, VallabhVidyanagar-Gujarat-India.

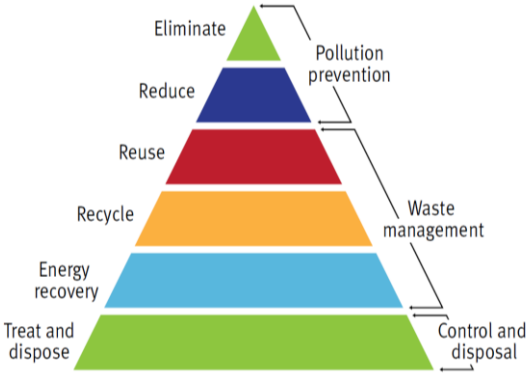

Fig.1 Demonstration of Waste Minimisation

Source:Reuse Options for Foundry Waste Sand – F10, Energy Eco-Efficiency Opportunities in Queensland Foundries

The basic reasons for reuse of used foundry sand and Pozzocrete for manufacturing of eco-efficient green concrete; are economic, technical and environment. Economically, the used foundry sand and Pozzocrete desire to reduce the total sand cost and fine aggregate; which includes purchase cost, freight cost, and disposal costs; while the purchase cost of natural sand, freight costs have gone up in the past. Environmentally, it is becoming more and more difficult to dispose of great quantities of these materials into the ground. Hence, there is a great need to utilize various industrial waste products in appropriate manner in construction industry to reduce health and environmental problems.

Recycling of foundry sand and Pozzocrete can save energy, reduce the need to mine virgin materials, and may reduce costs for both producers and end users. Use of these industrial wastes in construction applications offers project managers the ability to enhance green sustainable construction by reducing their carbon footprint, while also qualifying for LEED credits.

This paper provides a comprehensive overview of the engineering and construction properties of foundry sand and Pozzocrete for use in concrete as partial replacement materials.

The objectives of the study are:

- To select the Pozzocrete P60 and used foundry sand's mix proportion for concrete.
- To perform the experiments on compressive strength and water absorption of concrete with Pozzocrete P60 and used foundry sand. The strength was measured at the age of 7, 14 and 28 days; and water absorption was measured at the 28 days.

- To investigate changes in compressive strength and water absorption of concrete by utilization Pozzocrete and used foundry sand as partial replacement of cement and fine aggregates, respectively.

II. DESIGN MIX MATERIALS

A. Cement

The cement used is SANGHI OPC 53 grade cement. The Ordinary Portland Cement of 53 grades conforming to IS: 8112-1989is be used. Tests were conducted on the cement like Specific gravity, consistency tests, setting tests, soundness, Compressive strength N/mm^2 at 28 days.

Fig 2: SANGHI OPC 53 Grade Cement

TABLE – 1
PROPERTIES OF CEMENT

Sr.No	Physical properties of SANGHI OPC 53cement	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.15	3.10-3.15
2	Standard consistency (%)	31.5 %	30-35
3	Initial setting time (hours, min)	91 min	30 minimum
4	Final setting time (hours, min)	211 min	600 maximum
5	Compressive strength N/mm^2 at 28 days	58 N/mm^2	53 N/mm^2 minimum

B. Fine aggregate

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screen, to eliminate deleterious materials and oversize particles.

Fig 3: Fine aggregate (River sand)

ABLE- 2
PROPERTIES OF FINE AGGREGATE

Property	Fine Aggregate (River sand)
Fineness modulus	3.10
Specific Gravity	2.76
Water absorption (%)	1.20
Bulk Density (gm/cc)	1.78

C. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully.

D. Foundry Sand

Metalfoundriesuselargeamountsofthe Metal casting process. Foundries successfully recycle and reuse the sandmanytimesina foundry and the remaining sand that is termedas foundry sandis removed from foundry. This study presentstheinformationaboutthe civilengineeringapplications of foundry sand,which is technicallysound and environmentally safe.Useoffoundrysand in various engineeringapplicationscan solve the problemofdisposaloffoundrysandandotherpurposes.
Foundrysandconsistsprimarilyof silica sand,coatedwitha thin film of burnt carbon,residualbinder(bentonite,sea coal,resins) and dust.Foundrysand can be usedinconcretetoimprove its strength and other durabilityfactors. Foundry Sand can be usedasa partial replacement ofcementorasapartialreplacementof fine aggregates or totalreplacement of fine aggregate and as supplementary additionto achieve differentproperties of concrete.

Figure: 4 Used Foundry sand

Source: foundry industry, GIDC, VallabhVidyanagar

TABLE – 3
PROPERTIES OF USED FOUNDRY SAND

Constituent	Value (%)
SiO_2	87.91
$Al2O_3$	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
P_2O_5	0.00
Mn_2O_3	0.02

SrO	0.03
LOI	5.15
TOTAL	99.87

Source: R. Siddique, Waste Materials and By-Products in Concrete, Springer-200

D. Pozzocrete (P60)

Pozzocrete (P60) is a high efficiency pozzolanic material, obtained by selection, processing and testing of power station fly ash resulting from the combustion of coal at electricity generating power stations. It is subjected to strict quality control procedures. P60 confirms to IS: 3812 part-1 fly ash for use as a component of cement with Portland clinker.

TABLE- 4
GENERAL PROPERTIES OF POZZOCRETE

Property	P60
Presentation	Finely divided dry powder
Specific Gravity	2.3
Colour	Light Gray
Bulk weight (tonne per m^3)	1.0 tonne per m^3
Loss on Ignition	<2.5%
Particle size	<18% retained on 45 micron sieve
Particle shape	Spherical
Package	30 kg bags, 1 tonne big-bags and bulk tankers

III.DESIGN MIX METHODOLOGY

Concrete compositions

A cement concrete mix 1:1.48:3.21 was designed as per IS: 10262:2009 methods and the same were used to prepare the test samples. The design mix proportion is done in Table 5, 6 and 7.

TABLE - 5
M20 MIX DESIGN PROPORTIONS

	W (Lit)	C (Kg/m^3)	F.A. (Kg/m^3)	C.A. Kg/m^3)
By weight, [gms]	191.60	383.21	569.38	1231.11
By volume, [m^3]	0.5	1	1.48	3.21

W= Water, C= cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate

TABLE -6
CEMENT REPLACEMENT BY POZZOCRETE AND SAND REPLACEMENT BY USED FOUNDRY SAND

Sr. No.	Concrete Type	Description of Concrete
1	A0	Standard
2	C0	30% P60
3	C1	30%P60 + 10%FS
4	C2	30%P60 + 30%FS
5	C3	30%P60 + 50%FS

C.T.	W/C ratio	% Replacement		Design Mix Proportions For M20 Concrete (1:1.48:3.21)				
		C	F. A	C	F.A.	C.A.	U.F.S	P 60
A0	0.50	0	0	1	1.48	3.21	-	-
C0	0.50	30%	0	0.7	1.48	3.21	-	0.3
C1	0.50	30%	10%	0.7	1.33	3.21	0.14	0.3
C2	0.50	30%	30%	0.7	1.03	3.21	0.44	0.3
C3	0.50	30%	50%	0.7	0.74	3.21	0.74	0.3

TABLE - 7
DESIGN MIX PROPORTIONS FOR M20 MIX CONCRETE

C.T= Concrete Type C= cement, F. A. = Fine Aggregate,C. A. = Coarse Aggregate, U.F.S. =Used Foundry Sand

IV. EXPERIMENTAL METHODOLOGY

A. Testing methodology

The evaluation of Used Foundry Sand and pozzocrete for use as a replacement of fine aggregate and cement material begins with the concrete testing. Concrete contains cement, water, fine aggregate, coarse aggregate and grit. With the control concrete, i.e. 10%, 30% and 50% of the fine aggregate is replaced with used foundry sand plus 30% of cement replaced with pozzocrete,the data from the used foundry sand and pozzocreteis compared with data from a standard concrete without used foundry sand and pozzocrete. Three cube samples were cast on the mould of size 150*150*150 mm for each 1:1.48:3.21 concrete mix with partial replacement of fine aggregate with a w/c ratioo as 0.50 were also cast. After about 24 h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7,14 and 28 days for compressive strength and 28 days for water absorption tests.

B. Compressive strength

Compressive strength tests were performed on compression testing machine using cube samples. Three samples per batch were tested with the average strength values reported in this paper. The loading rate on the cube is 35 N/mm^2 per min. The comparative studies were made on their characteristics for concrete mix ratio of 1:1.48:3.21 with partial replacement of fine aggregate with used foundry sand as 10%, 30%and 50%.

Figure: 5 Setup of Compression Strength Testing Machine

C. Water Absorption Test

The cubes after casting were immersed in water for 28 days curing. They were then weighted and this weight was noted as the wet weight of the cube. These specimens were then oven dried at the temperature 100^0C until the mass became constant and again weighed. This weight was noted as the dry weight of the cube.

% Water Absorption = [(WW – DW) / DW] x 100
Where, WW = Wet Weight of Cube, DW = Dry Weight of Cube.

V. RESULT

TABLE -8
COMPRESSIVE STRENGTH OF CONCRETE (N/mm^2)FOR M20 MIX AT 7,14 & 28 DAYS

Types of Concrete	Average Ultimate Compressive Strength of Cement Concrete (N/mm^2)		
	7 days	14 days	28 days
A0	13.93	20.59	24.00
C0	19.11	27.85	29.19
C1	15.70	23.41	28.59
C2	20.74	28.74	31.11
C3	19.41	26.37	30.07

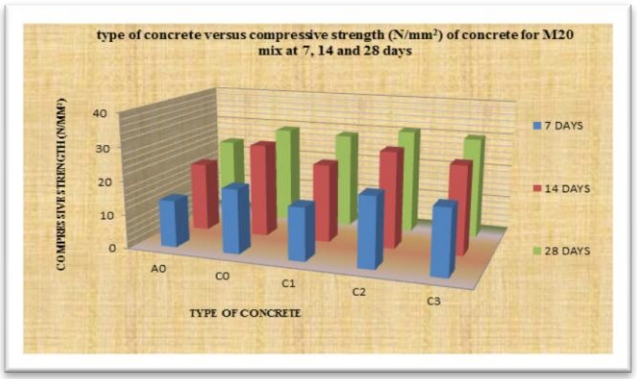

Figure: 6Type Of Concrete V/S Compressive Strength (N/mm^2)for M20 mix at 7, 14 And 28 Days

TABLE -9
WATER ABSORPTION OF CONCRETE (N/mm^2) FOR M20 MIX AT 28 DAYS

Sr. No.	Type of Concrete	Wet Weight of Cube In Grams	Dry Weight of Cube In Grams	%Water Absorption
1	A0	8330	8485	1.86
2	C0	8511	8681	2.00
3	C1	8583	8763	2.10
4	C2	8535	8696	1.89
5	C3	8901	9073	1.94

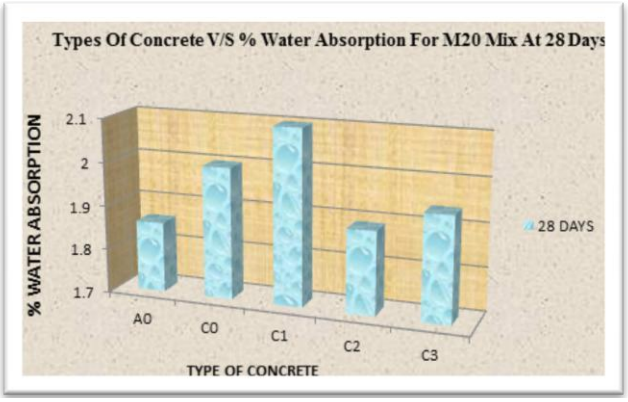

Figure: 7Types of Concrete V/S % Water Absorption for M20 Mix at 28 Days

VI. ECONOMIC FEASABILITY

TABLE- 10 COSTS OF MATERIALS

Sr. No.	Materials	Rate (Rs/Kg)
1	Cement (SANGHI OPC 53 grade)	6.00
2	Fine aggregate (Regional)	0.61
3	Coarse aggregate (Regional)	0.65
4	Pozzocrete (P60)	4.40
5	Used foundry sand	0.20

TABLE - 11
TOTAL CONSUMPTION AND COST OF MATERIALS FOR M20 DESIGNE MIX CONCRETE (1:1.48:3.21) PER m^3

C.T.	Consumption of Design Mix Proportions For M20 Concrete (1:1.48:3.21)					Total Cost /m^3	% Cost change
	C	F.A.	C.A.	U.F.S	P 60		
A0	383.21	569.38	1231.11	-	-	3446.80	0
C0	268.25	569.38	1231.11	-	114.96	3262.87	-5.34
C1	268.25	512.44	1231.11	56.94	114.96	3239.52	-6.01
C2	268.25	398.56	1231.11	170.82	114.96	3192.83	-7.37
C3	268.25	284.69	1231.11	284.69	114.96	3146.14	-8.72

C.T. = Concrete Types C= cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate, U.F.S. = Used Foundry sand

VII. CONCLUSION

From this study the following conclusion can be drawn:

- The results presented in this paper, indicate that the incorporation of a 30%Pozzocrete P60 mixed cement is feasible for strength.
- Pozzocrete P60 and foundry sand can be used in concrete to improve strength. Partial replacement of the Portland cement with Pozzocrete P60 and Partial replacement of fine aggregate with used foundry sandimprove strength.
- Also, it can be used in non-structural elements in the low range compressive strength where strength is not required.
- Pozzocrete P60 and used foundry sand can be used to prepared low cost temporary structure.

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- The results indicate that the % change in cost reduces up to 8.72 for 50% replacement of used foundry sand plus 30% replacement of pozzocrete.

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AUTHORS PROFILE

Dushyant Rameshbhai Bhimani was born in 1989 in Rajkot District, Gujarat. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishwakarma Mahavidyalaya, Sardar Patel University in 2011. At present he is Final year student of Master`s Degree in Construction Engineering and Management from Birla Vishwakarma Mahavidyalaya, Gujarat Technological University. He has paper published in international journal.

Prof. Jayeshkumar R. Pitroda was born in 1977 in Vadodara City. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 2000. In 2009 he received his Master's Degree in Construction Engineering and Management from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. He joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty where he is Assistant Professor of Civil Engineering Department with a total experience of 12 years in field of Research, Designing and education. He is guiding M.E. (Construction Engineering & Management) Thesis work in field of Civil/ Construction Engineering. He has papers published in National Conferences and International Journals.

Prof. Jaydevbhai J. Bhavsar received his Bachelor of Engineering degree in Civil Engineering from the Birla VishvakarmaMahavidyalaya, Sardar Patel University in 1978. In 1986 he received his Master's Degree in Building Science and Technology from University of Roorkee. He joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty where he is Assistant lecturer of Civil Engineering Department with a total experience of 32years in field of Research, Designing and education. He is guiding M.E. (Construction Engineering & Management) Thesis work in field of Civil/ Construction Engineering. He has papers published in National Conferences and International Journals.