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Modelling of The Properties of Sand Mould Made of Reclaimed Sand

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Abstract
Modelling of the properties of the sand mould made of reclaimed sand bonded with sodium silicate and cured with CO_2 gas is attempted in this paper. Properties considered are Mould hardness and Permeability. Regression models are developed and the correlation coefficient is determined. It is observed that the predictions of the model are matching with experimental values within +/- 5 % error.

I. INTRODUCTION

CO_2 moulds, owing to their superior mould hardness, are highly suitable for casting high density alloys like steel**.** Due to poor collapsibility of the mould, the subject of reclamation of CO2 moulding sand has gained importance. Literature reveals considerable amount of discussion on comparison of various alternate methods of reclamation but dry reclamation method is stated to be appropriate choice for silicate bonded sand moulds [1, 2]. In the literature most of the investigations carried out are on day to day basis in individual foundries but systematic investigation of the silicate bonded CO_2 process is yet to be attempted .hence in this paper it is attempted to model the process through multi-variety linear regression equation and the properties considered are Mould hardness and Permeability.

II. Objective &Methodology:

The main aim of the present investigation is to build up the experimental data of mould hardness and permeability of CO_2 gas cured silicate bonded sand mould made of reclaimed CO_2 sends and to develop regression models for predicting mould hardness and permeability.

i) Deciding the process parameters that affect mould hardness and permeability
ii) Choosing an experimental plan that portrays reasonably wide variation in values of process parameters
iii) Building up the necessary gassing arrangement and other attachments to prepare standard sand specimen
iv) Experimental determination of Mould hardness and Permeability
v) Development of Regression equation for Mould hardness and Permeability
vi)Testing the adequacy of the developed model

2.1 Deciding the process parameters that affect Mould hardness and Permeability

The process parameters considered are Percentage of Sodium silicate, Gassing time, mixing time and percentage of coal dust .Generally the percentage of sodium silicate used in the process is 3% to 6%. [3] and in the present investigation the considered sodium silicate percentage varies from 3% to 7% .To have one value beyond the range 7% of sodium silicate is chosen. The quantity of CO_2 gas is appropriately converted in to the gassing time by maintaining uniform pressure and flow rate of the CO_2 gas Uniform flow rate of CO_2 gas is ensured by special gassing arrangement shown in Figure-1...Too high mixing times make the mould friable after curing with CO_2 gas. A too low mixing time yield non uniform coating of sodium silicate binder on the sand grains and tells upon the properties of the mould. The mixing time ranges from five minutes to ten minutes. Generally, coal dust is added to the mix to improve the knock out properties too high amount of coal dust result in to mould of inferior strength and at the same time choke the pores between the sand grains and hence reduce permeability. Usually the coal dust percentage varies from 0% to 2% [3] and the same range is considered in the present investigation

3.2 Experimental Design matrix

Taguchi's experimental plan definitely provides a platform for systematic analysis of results to arrive at a meaning full conclusion .But Regression models developed based on limited number of experimental results may not represent the true situation .Hence larger number of experimental trial combinations are planned. Efforts are made to introduce adequate variation in values of process parameters (within the range of process parameters specified in the section 3.1) in the experimental plan and the experimental design matrix is given in Table-1

3.3 Experimental determination of Mould hardness and Permeability

Sand mixes are prepared as per the experimental plan shown in table-1 During the preparation of the sand mix initially the sand is dry mixed for one minute with coal dust additions if any and then mixing is continued by adding required quantity of sodium silicate for the remaining time of mixing. Standard sand specimen of 2'X2" size is prepared in a cylindrical tube. The rammed specimen along with cylindrical tube is kept in a special gassing arrangement for curing with adequate quantity of CO_2 gas. The hardness of the cured sand specimen is determined with the help of a scratch hardness tester .Similarly separate specimens are prepared and permeability of the specimens is determined. To be accurate enough each experiment is repeated thrice and the average values of Mould hardness and Permeability are shown in Table 1

Table-1 Experimental plan along with experimentally determined values of Mould hardness and Permeability

S.NO	% of sodium silicate	Gassing time	Mixing time	% of coal dust	Mould hardness No	Permeability No
1	3	8	5	0	38	800
2	3	13	6	1	46	640.63
3	3	20	7	2	53.3	521.32
4	3	22	8	0	57.5	550.66
5	3	28	10	2	61	321
6	3	26	5	0	50	683.33
7	3	30	10	2	66	301.6
8	4	8	5	0	53.1	640.66
9	4	20	7	2	60	462.5
10	4	28	10	1	63	370.33
11	4	26	5	2	60	418.23
12	5	8	5	0	66	505.66
13	5	13	6	1	68	418.33
14	5	20	7	2	65	344.33
15	5	28	10	1	68	340.66
16	5	26	5	2	70.3	380.66
17	5	28	7	0	65	362.33
18	6	8	5	0	78	301.66
19	6	13	6	1	78	266.33
20	6	20	7	2	77	275.33
21	6	22	8	0	70	370.6
22	6	28	10	1	66	302.66
23	6	26	5	2	80	301.6
24	6	28	7	0	76	380.6
25	7	20	7	2	80	196
26	7	28	10	1	70	282
27	4	13	5	0	55	624.66
28	4	13	10	2	56.66	400
29	4	30	5	2	63.33	421
30	4	30	10	0	68	410.8
31	6	13	5	2	79	264
32	6	13	10	0	65.33	298.33
33	6	30	5	0	81	462.1
34	5	22	10	0	66	364
35	5	30	5	1	74	245.5
36	6	22	5	2	77	321
37	6	30	7	0	77.3	421.3
38	6	30	10	2	64	238

Table-2: Experimentally obtained values of Mould hardness and Permeability vis-à-vis predicted values from the model along with error percentage

S.NO	Mould Hardness			Permeability		
	Experimental	Prediction Through model	Error %	Experimental	Prediction Through model	Error %
1	38	39.56	-4.1	800	782.51	13.05
2	46	45.27	1.6	640.6	656.28	-2.43
3	53.3	52.27	1.93	521.3	509.40	2.29
4	57.5	56.18	2.28	550.66	559.29	-1.56
5	61	65.02	-6.5	321	348.15	-8.45
6	50	51.18	-2.36	683.33	596.58	12.69
7	66	66.31	-0.47	301.6	327.5	-8.6
8	53.1	52.07	1.92	640	627.10	2.1
9	60	59.23	1.27	462.5	425.01	8.1
10	63	65.39	-3.8	370.33	365.87	1.2
11	60	60.56	-0.19	418.33	439.5	-5.06
12	66	64.59	2.13	505.66	471.68	6.71
13	68	65.08	4.28	418.33	405.92	2.97
14	65	66.2	-1.84	344.33	340.63	1.07
15	68	65.72	3.35	340.66	335.21	1.59
16	70.3	70.04	0.36	380.66	379.18	0.38
17	65	68.76	-5.78	362.33	368.1	-1.67
18	78	77.11	1.14	301.66	316.26	-4.85
19	78	74.99	3.84	266.33	280.74	-5.41

20	77	73.16	4.98	275.33	256.25	6.92
21	70	70.77	-1.1	350.66	349.3	0.33
22	66	66.04	-0.07	302.66	304.55	-0.67
23	80	79.51	0.6	301.6	318.86	-5.72
24	76	74.37	9.29	380.6	397.16	-4.3
25	80	80.12	-0.16	196	171.86	12.3
26	70	66.37	5.18	282	273.89	2.9
27	55	54.46	0.96	624.66	601.86	3.64
28	56.66	58.19	-2.71	400	393.19	1.7
29	63.3	62.47	1.31	421	419.32	0.42
30	68	66.39	2.35	410.8	404.16	1.61
31	79	77.71	1.63	264	247.1	6.34
32	65.33	64	2.02	298.33	270.13	9.44
33	81	80.17	1.02	462.1	437.69	5.28
34	66	63.92	3.15	364	382.17	-4.99
35	74	71.32	3.61	406.7	428.5	-5.4
36	77	78.96	-2.54	321	296.78	7.54
37	77.33	74.65	3.46	421	408.2	3.1
38	64	66.27	-3.5	238	267.21	-12.27

3.4 Building up of the necessary gassing arrangement and other attachments

The success of experiment depends on supply of exact quantity CO_2 gas and uniformly to every part of the standard sand specimen To ensure this a gassing arrangement is built up providing supply of CO_2 gas at uniform pressure and flow rate with the help of a rotameter arrangement Gassing arrangement setup consists of CO_2 gas cylinder rota meter, Nozzle, Pressure gauge and flexible hose pipe. The gassing arrangement is shown Fig-1 Uniform flow of the CO_2 gas in to every nook and corner of the sand specimen having a cylindrical cup with perforations on the inner surface

3.5 Development of Regression equation for Mould hardness and Permeability

As per the experimental value of Mould hardness the normal equations are developed and the regression coefficients are calculated .Interactions Sodium silicate Vs Gassing time and Sodium silicate Vs mixing time are also considered in computing the regression coefficient. With the help of the regression coefficient values the following Regression model is developed

Mould hardness of the CO_2 Sand mould made of reclaimed CO_2 Sand (MH rec).

MH rec=-46.2844+22.68 *a1+1.152*b1+7.817*c1-0.048*d1 -0.1688*a1*b1-1.7628*a1*c1 (1)

The regression correlation coefficient is found to be 0.98

Similarly the following regression model is developed for assessing the permeability

Permeability of the CO_2 Sand mould made of reclaimed CO_2 sand (P rec)

Perm rec=1646.4926-216.776*a1-26.1784*b1-37.6593*c1-48.3793*d1+5.283*
a1*b1+3.8190*a1*b1+3.8190*a1*c1 (2)

The regression correlation coefficient is found to be 0.96

3.6 Testing the adequacy of the developed model

The developed model is tested by making the predictions at various values of process parameters and the error percentage is computed with respect to the experimentally obtained values and error percentage for both Mould hardness and Permeability are given in Table-2

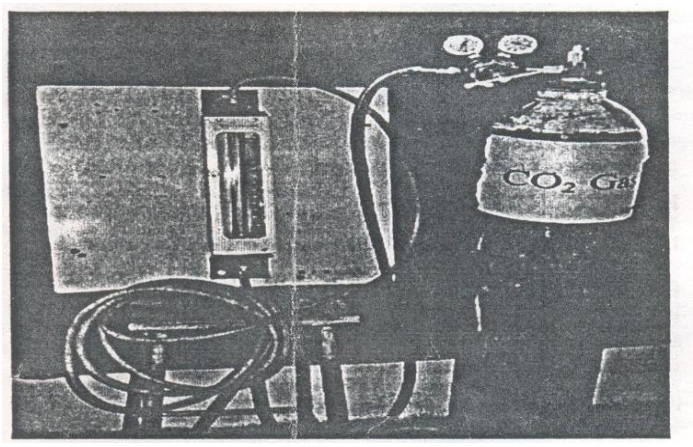

Fig-1 Gassing arrangement setup

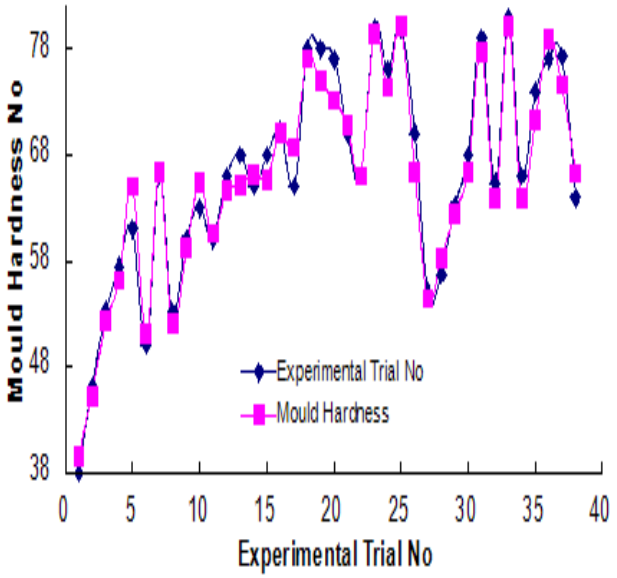

Fig-2: Experimental values of Mould Hardness vis-à-vis Predictions from the model.

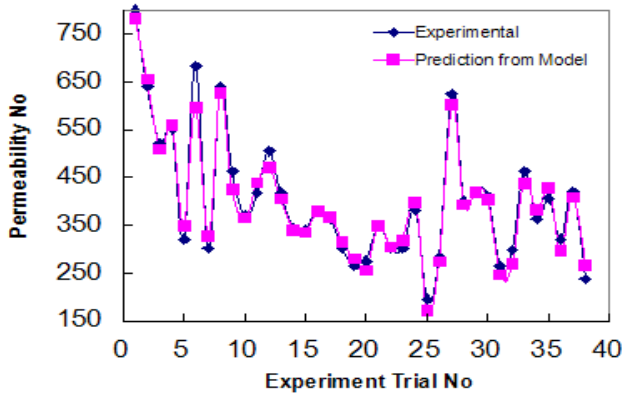

Fig-3: Experimental values of Permeability vis-à-vis Predictions from the model.

IV. DISCUSSION OF THE RESULTS

It can be observed that the mould hardness value increases as the percentage of sodium silicate increases .The coal dust addition, though increase collapsibility but includes permeability .This is because the fine coal dust may choke the pores existing between the sand grains. At lower percentages of sodium silicate higher gassing time leads to decrease in Mould hardness. The reason could be the over gassing of the sand specimen. Literature reveals that it is better to under gas rather over gassing

Table-2 ,Fig-2 and Fig-3 reveals that the error percentages in more than 90% of the cases is around 5% But in very few cases the error crept to around 10%..This is confirmed by the corresponding regression correlation coefficient whose values are leaning around 0.98 .Higher values of correlation coefficients and lower deviation of predicted values from experimental values indicates the adequacy of the developed model..Literature reveals that an Artificial Neural Network with back propagation learning algorithm could perform much better[4] Presently the authors are trying various alternative Neural network architecture to model the properties of Reclaimed CO_2 sand mould

V. CONCLUSIONS

It is concluded that Multi-variety linear regression model suit well to model the Mould hardness and Permeability of the CO_2 gas cured silicate bonded sand moulds. Literature suggested application of Artificial Neural network model for making the predictions much more accurately in such cases and hence attempts are in progress in this direction

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