Reclamation and Utilisation of Foundry Waste Sand

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ABSTRACT

The reclaimed sand was subjected to sand moulding by using sodium silicate and clay as binder. The effect of reclamation with wet and dry process on the performance of the foundry waste sand had been tested in the laboratory scale. The performance of the sands were investigated through measurement of compressive, shear strength and permeability number of the mould specimens.

Based on the present experimental results, it was observed that the wet reclaimed sand showed superior performance to the dry as far as compressive strength was concerned when sodium silicate was used as the binder. In the case of clay binder both dry as well as wet reclaimed sands were found to have comparable compressive strength.

Key words: Foundry waste sand, reclamation, utilization, characteristics.

1. INTRODUCTION

The foundry industry generates a number of byproducts of which the largest volume is "spent sand". Molding sand is mixed with binder and additives. The characteristics of the residuals vary from foundry to foundry, and depend on the type of metal being poured, the type of casting process, the technology employed, and the type of finishing process. Foundry waste sand is physically suitable for many applications /1-7/ although long-term environmental effects are not well documented. The beneficial use of waste sand requires specific physical and chemical characterization of the waste material. Results of waste characterization should identify hazardous wastes, determine disposal needs and other issues.

Economic and environmental concerns dominate the issue of recycling foundry sand. The presently accepted practice of spent sand disposal in landfills is becoming an economic burden for foundries as land filling becoming costly and regulations grow stricter. Furthermore, technical and economic feasibility issues are raised for foundries that want to beneficially use their spent sands. The foundry waste sands can be put to work by reclamation or other constructive use. In the process, money saved may be put into producing castings.

Currently, there are no universally accepted definitions for the terms recycling, reclamation, and reuse. Recycling of materials implies that there exists a commercially demonstrated processing or

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manufacturing technology, which uses the material as a raw material. Reclamation requires specialized machinery that recovers a quality portion of the spent sand applicable to further use in mold or core making. “Beneficial use” is any further use, other than the original use, of a discarded material or by-product that would otherwise become waste.

The reclamation /6-12/ of spent foundry sand is a complex problem driven by economics. It has been said that sand reclamation is not one process but a combination of processes. Whether reclamation is economically feasible depends on how well the foundry is able to process its various sources of spent sand.

The approach to reclamation must begin by identifying all sources of spent sand in the foundry, and determining the quantity and characteristics of the sand from each of those sources. The next step is to determine the least amount of processing necessary to each of these sources, which will render the sand usable in the foundry.

There are three prime reasons for reclamation to be done.

In many reclaimed sand trials, when the sand has been cleaned properly, the casting quality is as good, if not better, than new sand. The reclamation is effective when the grain size distribution is similar to the original new sand distribution, thus new make-up sand should be purchased to the same specifications and not with any special distribution to make up for the inadequacies of the reclamation equipment.

In dry reclamation process /7-9,11/ fines, free clay, fractured sand grains and iron oxide particles etc., are removed from the used sand. However, since it is not possible, by this process, to remove clay, organic and carbonaceous materials completely from the sand grains, dry reclamation does not restore the original quality of the sands.

In wet reclamation process /6-8/, clay bonded molding sand can be reclaimed very effectively, since the residual clay goes into suspension readily. High water requirements for the system along with even stricter Environment Protection Agency (EPA) regulations on wastewater disposal have restricted the use of wet reclamation. The technique has received renewed investigation because of the growing interest in the use of inorganic binders, particularly silicate binders. Wet reclamation is particularly well suited to reclaim such sands.

Beneficial reuse for the foundry spent sands has been reported /1-7,10,11/ to be in the areas of land fill, structural fill, road base, bricks, pavers, flowable fill, Portland cement, mortars, asphalt concrete etc.

In the present work spent sand was collected from the nearby industry and was subjected to laboratory scale reclamation processes (details are described in the experimental section). The spent and reclaimed sand was characterized through various techniques, viz, loss on ignition, density measurement, chemical composition analysis, determination of grain fineness number etc. The sand grains were also characterized in terms of their grain shape and size through optical microscopy.

The reclaimed sand grains were then utilized to make sand specimens by normal foundry techniques /13,14/. The sample specimens were then subjected to compressive, shear strength, and permeability measurement to assess the performance. The objective of the present work was to see the effect of reclamation on the performances of the sands.

2. EXPERIMENTAL FOR SAND RECLAMATION

2.1: Dry Reclamation

10 kg of spent sand lumps was taken and put in the container of the ball mill along with 2 kg of ceramic balls of appropriate sizes. Then the ball mill was rotated very slowly (about 5 rpm) along with the spent sand lumps for 5 minutes. During this process lumps were broken and the hardened binder was also separated out from the sand. The sand was collected from the ball mill and was screened (-1.5mm +0.05mm). Due to this screening the dust, fines and metallic particles present in the sand were removed.

2.2. Wet reclamation

The sand lumps of about 10 kg were placed in a big container with 10 litres of water added, scrubbed by a wooden rod from time to time to break the lumps and to disperse the sand grains, binders etc and the sand was allowed to remain in water for about 48 hours. The sand
was recovered by decanting and removing the water, dissolved binder etc. The wet dispersed sand was then dried in an oven at 388K for 1 hour and screened (-1.5mm +0.05mm). The weight of the retained sand was taken.

2.3 Characterization of sands

The spent sand, dry reclaimed sand, wet reclaimed and new sand was characterized by measurement of composition, loss on ignition test (LOI), density and AFS grain fineness number. Standard test specimens were prepared in batches using various quantities of binder in laboratory type mixer. Two batches of experiments were conducted. In one batch different sets of specimen samples were prepared using different compositions of sodium silicate, whereas in another batch sample specimens were prepared using various quantities of bentonite as binder. The green sand mixtures were prepared in Simson type batch muller. The test specimens prepared for strength measurement were of cylindrical shape of diameter 0.051metre and height 0.051metre prepared by standard foundry practice /13,14/ using three ram technique. The specimens prepared with Na₂SiO₃ were subjected to carbon dioxide gassing treatment for 30 seconds. Measurement of compressive strength was carried out by the standard sand testing procedures /13/. The grain shape and the nature of the sands were investigated through optical microscopic studies.

In order to investigate the performance of the reclaimed sands finally a mould was prepared using the wet reclaimed sands, 5% clay as binder and 4% water. After skin drying the mould and storing in the ambient conditions for 24 hours gray cast iron was cast.

3. RESULTS AND DISCUSSIONS

The results of compositional analysis, LOI, density of the sands are shown in Table 1. The low < 2% LOI value suggests that spent sand was mostly of sodium silicate & clay bonded sands; sands containing organic binders show higher LOI values.

Compositional analysis showed that these spent sands may be a good source of SiO₂, Al₂O₃, Fe₂O₃ (viz., SiO₂: 93-94%; ), which may support the needs where such mineral oxide supplement is required. Low % alkali content (Na₂O 0.45% and K₂O:0.02%) in wet reclaimed sands justified washing out of Na & K during wet reclamation process. Other constituents such as CaO, MgO etc were negligible, which suggests that the spent sands used did not have the slags pertaining to cupola & Arc furnaces. It had been confirmed through compositional analysis of sand samples brought at different times that the composition of the spent sand varied, which depends on the variant sources of the sands.

![Table 1](attachment:image.png)

Results of grain fineness number (GFN) and the sieve analysis are shown in Tables 2-4, respectively. It was found that the grain fineness number of wet reclaimed sands was 49.29, which was comparable to GFN value of fresh sands as 51. The Sieve analysis illustrates that major sand grains were in the size grades of 0.71 mm to 0.18 mm which constituted consecutive 4-5 sieves. In the fresh sands, wet reclaimed and dry reclaimed sands the size grades of 0.71 mm to 0.18 mm were found to be about 97%, 87% and 76% respectively. And the rest of the sand grains were mostly below the size grades of 0.18 mm.
### Table 2
Calculation of AFS grain fineness number of fresh sand

<table>
<thead>
<tr>
<th>Sand retained on sieve (mm)</th>
<th>Amount of 50 gms sample retained of sieve</th>
<th>Multiplier</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.6</td>
<td>15</td>
</tr>
<tr>
<td>0.71</td>
<td>0.4</td>
<td>0.8</td>
<td>35</td>
</tr>
<tr>
<td>0.5</td>
<td>10.1</td>
<td>20.2</td>
<td>25</td>
</tr>
<tr>
<td>0.355</td>
<td>0.6</td>
<td>1.2</td>
<td>35</td>
</tr>
<tr>
<td>0.25</td>
<td>8.1</td>
<td>16.2</td>
<td>12</td>
</tr>
<tr>
<td>0.18</td>
<td>29.3</td>
<td>58.6</td>
<td>60</td>
</tr>
<tr>
<td>0.125</td>
<td>0.2</td>
<td>0.4</td>
<td>81</td>
</tr>
<tr>
<td>0.063</td>
<td>0.5</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Pan</td>
<td>0.1</td>
<td>0.2</td>
<td>275</td>
</tr>
</tbody>
</table>

Total % retained = 99.6  
Total product = 5080.4

AFS GFN of fresh sand = 5080.4/99.6 = 51

### Table 4
Calculation of AFS grain fineness number of dry reclaimed sand

<table>
<thead>
<tr>
<th>Sand retained on sieve (mm)</th>
<th>Amount of 50 gms sample retained of sieve</th>
<th>Multiplier</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.6</td>
<td>9</td>
</tr>
<tr>
<td>0.71</td>
<td>1.2</td>
<td>2.4</td>
<td>12</td>
</tr>
<tr>
<td>0.5</td>
<td>9.8</td>
<td>19.6</td>
<td>25</td>
</tr>
<tr>
<td>0.355</td>
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<td>2.8</td>
<td>35</td>
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<tr>
<td>0.25</td>
<td>3.4</td>
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<tr>
<td>0.18</td>
<td>21.9</td>
<td>43.8</td>
<td>60</td>
</tr>
<tr>
<td>0.125</td>
<td>6.1</td>
<td>12.2</td>
<td>81</td>
</tr>
<tr>
<td>0.09</td>
<td>4.1</td>
<td>8.2</td>
<td>118</td>
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<td>0.063</td>
<td>0.3</td>
<td>0.6</td>
<td>164</td>
</tr>
<tr>
<td>Pan</td>
<td>1.3</td>
<td>2.6</td>
<td>275</td>
</tr>
</tbody>
</table>

Total % retained = 99.6  
Total product = 6332.6

AFS GFN of dry reclaimed sand = 6332.6/99.6 = 63.58

### Table 3
Calculation of AFS grain fineness number of weight reclaimed sand

<table>
<thead>
<tr>
<th>Sand retained on sieve (mm)</th>
<th>Amount of 50 gms sample retained of sieve</th>
<th>Multiplier</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>0.7</td>
<td>1.4</td>
<td>9</td>
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<tr>
<td>0.71</td>
<td>10.2</td>
<td>20.4</td>
<td>15</td>
</tr>
<tr>
<td>0.5</td>
<td>8.5</td>
<td>17</td>
<td>25</td>
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<td>1</td>
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<td>0.25</td>
<td>1.8</td>
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<td>45</td>
</tr>
<tr>
<td>0.18</td>
<td>22.3</td>
<td>44.6</td>
<td>60</td>
</tr>
<tr>
<td>0.125</td>
<td>3.7</td>
<td>7.4</td>
<td>81</td>
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<tr>
<td>0.09</td>
<td>1.2</td>
<td>2.4</td>
<td>118</td>
</tr>
<tr>
<td>0.063</td>
<td>0.4</td>
<td>0.8</td>
<td>164</td>
</tr>
<tr>
<td>Pan</td>
<td>0.5</td>
<td>1</td>
<td>275</td>
</tr>
</tbody>
</table>

Total % retained = 99.6  
Total product = 4905.4

AFS grain fineness number of wet reclaimed sand = 4905.4/99.6 = 49.25

The sand grain size plays an important role in the molding properties such as compactibility, binder requirement, surface finish etc. It was suggested by Jain /13/ and Heine /14/ that if the sand grain size in the consecutive 4-5 sieves contained about 80 to 95% of the sand grains then it is expected that it will have better compacts and will have less erosion. The grain size distribution also shows the presence of adequate amount of finer grains which are expected to give better compaction of mold, better surface finish, less metal penetration and better compressive strength.

Sands were subjected to molding using 3%, 4%, 5% and 6% $Na_2SiO_3$ as binder and hardening by $CO_2$. Mould specimens were then subjected to measurement of compressive and shear strength and permeability. The trend of change of green compressive strengths (GCS) with binder was shown in the Fig. 1. It was observed that GCS of wet reclaimed sands almost resembles that of new sands; whereas GCS of dry reclaimed sands were far below that of wet reclaimed sands & new sands. This might be due to typical granulometry as shown in Table-4 and due to residual burnt binders in...
the dry reclaimed sands. Burnt binder might be the inhibitor for proper bond development and may be responsible for low GCS of dry reclaimed sands. Higher GCS values for wet reclaimed sand suggested that they may be utilized as facing sand as well as core sands, where as low strength of dry reclaimed sand suggests that they may be utilized as backing sand. The shear strength and permeability of the sodium silicate bonded specimens were shown in Fig. 2 and Fig. 3 respectively. The trend in change of shear strength almost resembled to that of GCS. The permeability decreased with increase in sodium silicate content.

**Fig. 1:** Compressive strength using sodium silicate as binder

**Fig. 2:** Shear strength using sodium silicate as binder
A similar effort was made to study the effect of clay binder on the strength development on the reclaimed sands. The green compressive strength, green shear strength and permeability were measured for new sands, wet and dry reclaimed sands by using 4%, 5%, 6% and 7% bentonite clay and 5% water; in each case the mixing time was 5 minutes. The trend of change of GCS is shown in Fig. 4. It was observed that the green compressive strength of dry reclaimed sand was more at lower additions of clay (e.g., 4% and 5%) in comparison to that of the new sand and wet reclaimed sand, which of course was nullified with further additions of the clay binder (e.g., 6% and 7%). The reason might be due to the residual clay content of the dry reclaimed sand, which was 2.8% and was responsible for higher GCS of the specimens at lower clay binder additions. But in case of wet reclaimed sand residual clay content was 0.8%. It was observed that in the batches containing 6% and 7% bentonite all the sands had comparable GCS as shown in Fig. 4. Therefore, it may be suggested that both dry and wet reclaimed sand may equally be utilized for foundry use especially in green molding process using bentonite clay depending on the requirements. The trends in change in shear strength and permeability were shown in Fig. 5 and Fig. 6 respectively.

Shear strength followed an almost similar pattern to that of compressive strength. The permeability values indicated the state of compaction which simultaneously depends on the number and size of the pores. The volume of pores in such granular materials depends on the mode of packing, including the effect of additives, binders, mulling time, bulk density etc.
Fig. 4: Compressive strength using bentonite

Fig. 5: Shear strength using bentonite
Fig. 6: Permeability using bentonite as binder

Fig. 7: Surface characteristics of spent sand, 30X

Fig. 8: Surface characteristics of wet reclaimed sand, 30X
In order to study the differences in surface characteristics of these sands, samples of spent sand, wet and dry reclaimed sands were subjected to optical microscopic investigations at 30X magnification. Figures 7-9 show the microphotographs. The microscopic photo of spent sand shown in Fig. 7 illustrated that sand grains were agglomerated and binder appeared to be covered most of the surfaces of the grains. Some of the burnt binder films were visible. The wet reclaimed sand grains as shown in Fig. 8 appeared crystalline in nature, round to sub angular in shape and washed off the binder. Some of the burnt sand grains were also visible in wet reclaimed sands. The dry reclaimed sands shown in Fig. 9 illustrated that grains were more of rounded in shapes and majority of the sand grains were covered with binder layers. Presence of burnt binder film was visible. However, at this stage it needs mention that when the reclamation is done in industries the sand grains faces much more stringent manufacturing conditions which consequently affects the grain shape and granulometry and the performances of the sands are expected accordingly.

In order to study the effect of sand on the casting quality a mould was prepared with wet reclaimed sand using sodium silicate as binder. Gray cast iron was used and the casting was made. It was observed that the casting finish was uniformly good using wet reclaimed sand grains.

4. CONCLUSIONS

The work identified several issues. Variations in composition of the spent sands from plant to plant depends on the generating sources of the sands. A typical foundry can generate from 8 to 30 individual waste products, including spent molding sand, core sand waste, cupola slag, arc furnace slag, scrubber sludge, bag house dust, shot blast fines and others. Identification of each generation point is important to understand the reuse possibilities of the spent sand, depending on the composition & physicochemical characteristics.

Based on the investigations and experimental results, it was observed that the wet reclaimed sand shows superior performance to the dry reclaimed sands as far as compressive strength was concerned when sodium silicate was used as the binder. In the case of clay binder it was observed that both dry as well as wet reclaimed sands had comparable compressive strength. The permeability values indicate the state of compaction which simultaneously depends on the number and size of the pores. The volume of pores in such granular materials depends on the mode of packing, including the effect of additives, binders, mulling time, bulk density etc.

It may be said that there may not be one particular reclamation process that will satisfy all foundry demands since there are many variable factors, which controls the reclamation process in foundry. In brief the variable factors may be

i) type of sand used
ii) type of binder that has to be removed from the sand to be reclaimed
iii) type of binder to be reused
iv) type of metal to be poured etc.

All these factors greatly influence the economics of sand reclamation for a particular foundry. Accordingly the selection of the appropriate reclamation equipment is also a big task.

It could be concluded that all non-hazardous foundry waste sands need not to end up in landfill. These wastes can be put to work by reuse, reclamation or by other means of constructive use.
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REFERENCES