Various Alternative Sources for Silica Sand, Binders and Additives in Sand Casting and their Properties – A Review

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Abstract Foundries all over the world consume silica sand, clay binders and additives to some proportion for production of green sand castings. Silica sand apart from being used for mould making and core making, it is also used in many areas such as glass making, and construction etc., Consumption of silica sand in large quantities will lead to the depletion of these resources. If an alternative source is identified, the demand on single source will be avoided and the cost of the sand can be lowered drastically. Apart from conventional binders and additives for sand moulding different organic binders and additives are also available by which the sand mould properties can be improved according to the material cast like cast iron, steel, aluminum, brass etc. The search for different alternative sources in sand moulding can lead to good quality sand casting at reduced production cost.

Keywords: alternative sources; silica sand; sand mould properties; binders; additives

1. Introduction
Silica sand used in foundry contains high proportion of SiO\textsubscript{2} (more than 95%) and less than that are used as construction aggregates. Silica sand also serves as raw material for glass making and wide range of other industrial and horticultural applications. Silica sands are costlier than the construction sands and this encourage serving wide geographical market, including exports. Naturally available silica sands used in the past are of less economic importance today and the demand is for clay free silica sand which has high silica content. The binding agents like bentonite, chemicals and resins are added for mould and core making which increases the production cost of castings. The green sand moulding and its quality is based on many process and input parameters,ie, grain size, micro profile shape of the sand, binder and clay which are complex in nature.

1.1 Alternative Sources for Moulding Materials
Some of the alternative sources that have been used as a moulding material are listed below,

- Tailing Sand
- Silica free Sand
• Fly Ash
• Chromite Sand
• Olivine Sand
• Ferro Chrome Sand
• Blast furnace slag
• Alumina
• Cassava starch
• Soluble Sodium Silicate binder
• Gum Arabic
• Tamarind powder and Coconut shell powder
• Corn Cob stem and ash of Rice Husk

1.1.1 Tailing Sand

After tin extraction the residue minerals obtained is called tailing sand. The silica content of tailing sand is in the range of 94 to 99.5 percentage. Malaysia’s Kinta Valley has large volume of this sand. It has high permeability. It is an important property for sand casting process where the gases formed after pouring molten metal into moulds finds passage for escaping to produce defect free casting.

1.1.2 Silica free Sand

Silica-free minerals are by-products of construction aggregates that are costeffective replacements for foundry silica sand. The major health and safety issues associated with using silica sand can be rectified by using silica free sand with suitable binders and additives. Sand reclamation technology will enable foundries to change to silica-free sand and/or reduce minimize total sand costs per unit of good casting produced.

1.1.3 Fly Ash

Fly Ash is a waste residue coming out from the combustion of thermal power plants. It is a fine powdery residue of spherical particles generally in the size range of 0.5 to 100 micron. Generally the fly ash consists of nearly 50% silica. They can be mixed with silica sand for mould making. They do have very high melting point.

1.1.4 Chromite Sand

Chromite sand occurs naturally and it consists of oxides of chrome and iron. It has sub-rounded grains form with more polished surfaces with 85 AFS fineness number and it does not require crushing and can be used directly in the mould. High thermal conductivity which gives good chilling properties to casting, low thermal expansion property produces good dimensional stability castings and also it has a high refractoriness. When chromite sand is used as moulding sand wide range of resin bonding systems and inorganic binders can be used.
1.1.5 Olivine Sand

Olivine sand is special sand used to maximize the bond performance and it can produce strong chemically bonded mould. The casting defects like shrinkage cavities can be eliminated equally in ferrous/non-ferrous green-sand castings. Burn-in penetration defects are reduced and lower cleaning casts are achieved.

1.1.6 Ferro Chrome Slag

This is a slag mainly coming from industrial solid waste generated in alloys plant. Globally, it is coming around between 6.5 to 9.5 million tons annually. It is available in large quantity and gives same physical/chemical properties while mixing with silica sand. Investigations can be done to find out the appropriateness of this slag as an alternative.

1.1.7 Blast Furnace Slag

It is a by-product of smelting ore used to separate the metal. It can commonly available as a mixture of silicon dioxide and metal oxides.

1.1.8 Alumina

Alumina which is a refractory material is added to the green sand mould which increases the strength of green and dry compression sand and permeability of the recycled one. The foundry sand should be recycled for economic reasons and by adding additives like bentonite the green compressive strength is increased. To improve dry and hot compression strength of recycled green sand, addition of alumina improves the mechanical properties.
1.19 Cassava Starch

Cassava is a cheap source of starch abundantly found in Kenya. It has excellent bonding characteristics. It poses no health hazard and is environment-friendly for the production of sand cores. It also reduces dependence on imported, costlier sources as moulding materials for production of castings.

1.10 Soluble Sodium Silicate Binder

This binder will offer a good knocking out properties in moulding applications, without compromising the level of strength properties. Collapsibility is an important property for moulding sand and especially for cores where the sand materials should be free to collapse after the casting has been solidified to prevent cracks and tear in final casting.

Figure 8 Soluble Sodium Silicate Binder

1.11 Gum Arabic

Gum Arabic also named as acacia gum. It is a natural gum available on acacia tree. It has adequate bonding strength, shatter index and hardness. But the green permeability of this binder is very low.

1.12 Tamarind powder and Coconut shell powder

Tamarind powder is practiced as an additive to silica sand mould and it is produced by pulverizing the tamarind seeds to a powder form, it is an agricultural waste available abundantly. Coconut shell powder is taken out by grinding the coconut shell to a fine powder form. The tamarind and its powder fineness provide good strengths in compression/shear load. The permeability number is also in higher side.

Figure 10 Tamarind and Coconut shell powder (natural type)

1.13 Ricehuskandcorncob

By products from paddy and corn are huskandcorncobare actually agricultural waste. They are rich in silicacontents. Theseagriculturalwastes and their ashes have goodbindingproperties. Moreover, very fine grain sizes are there in pulverizedform so that they can act as good blend with silica sand.
 compression/shear strengths acted positively with the increase in additives weight percentage.

2. Literature Survey

A. Abdullah et al. [1] investigated the samples of tailing sands collected from tin mines. The sand mixture used 4% clay and it gives higher permeability compared extra 4% clay. Kenneth P. Harris [2] used silica-free foundry sans for investigation. They are by-products of construction aggregates. It may reduce specific sand and binder consumption. The organic binders can be exchanged with cheap inorganic binders. Jerzy Sobczak and Mr. Robert M. Purpert[3] researched to use Fly ash wasted from the thermal power plant with various binders to make the mould. The prime properties like green compression strength and permeability were carried out to find the viability of alternative. Investigation carried out reveals that maximum of 20% can be used for mould making. Daryl F. Hoyt [4] found that O” chromite sand can be used to yield quality cores with phenolic urethane or coldbox binders. The cores produced by this sand have high properties when compared to other speciality sand. Blending of finer chromite sand with other aggregates can produce properties higher than other sands.

Tataram.K. Chavan and H.M. Nanjundaswamy [5] found that Olivine sand has lower free silica content, good refractory properties and strong resistance to metal attack. Olivine sand is less stable under thermal shock conditions than zircon sand or chrome sand, but its thermal expansion is much less than silica sand. The presence of hydrous magnesium silicates (serpentine) may contribute to pin holing or pock marking when olivine sand (uncalcined) is used in the production of low carbon steel castings. Olivine sand particles are less durable than other non silica sands, although it has comparable hardness. Narasimha Murthy et al. [6] analysed and investigated that Highsilicasand that is commonly used in foundry industry. K. Thirupathi Rao and A. Suresh Babu [7] investigated an alternative solution for the future generation. It is obtained by the reduction in usage of moulding sand. It is witnessed that the moulds produced with extra slag have extra permeability compared with the sand moulds.

A.K. Birru et al. [8] investigated that Alumina, which is a refractory material, have the possibility to improve permeability and the green and dry compression strengths. A comparison was made with green sand and recycled green sand and found that extra alumina improves the mechanical properties. Experiments were conducted at 0.2%, 0.4%, 0.6% alumina addition, it is found that in 0.2% alumina addition the permeability was 2450; Green compression strength value was 880 and Dry compression strength 3300 gm/cm2, which is...
found to be optimum. Oyetunji et al. [9] investigated that Good quality cores can be successfully produced using cassava starch in combination with Iyoloko clay. Core is produced by mixtures containing 8-12% starch, 5% clay and 6-10% water after baking between 150° and 180°C for 2 hours. It is found that cores with optimum properties were from mixtures containing 10% starch, 5% clay and 10% water. The green and baked shear strength values from these tested cores were 31.1 KN/m² and 498.1 KN/m² respectively. The strength values obtained from these tested cores show that they are suitable for the production of iron and non-ferrous castings. Izdebska-Szanda et al. [10] investigated that soluble sodium silicate binders which are inorganic binders and non-toxic in nature. Nuhu A. Ademoh, and A.T. Abdullahi [11] investigated the Sand specimens bonded with the gum Arabic at different proportions with standard foundry tests. The result showed the exact percentage of binder content in powdered form is suitable for non-ferrous alloys, malleable and grey iron and steel. Tataram K Chavan and H.M.Nanjundaswamy [12] investigated the effect of fly ash, tamarind powder and coconut shell powder as an additive to silica sand in different proportion on green sand mold. It is found that green compression and shear strength of tamarind powder as additive that gives better strength as compared to fly ash and coconut shell powder. Tamarind powder has high fineness so higher green and shear strength can be obtained by using tamarind powder Aribo [13] investigated the use of ash from ricehusk andncorncob as an alternate aggregate for foundry mouldings. Equal mixture proportion was used. The results revealed that green strengths, moisture and permeability behaved negatively with increase in the additives.

3. Conclusion and Further Scope
The proposed work focuses on listing some of the possible alternative sources as moulding materials for production of green sand casting. The consumption of silica sand to some proportion can be reduced by replacing it with suitable moulding materials without compensating quality and further production cost of casting can be lowered. The health issues associated with silica sand in foundry can also be rectified if it is replaced by silica free minerals with suitable binder and additives. Moreover depending on a single source for casting production can be avoided which gives flexibility for selecting various moulding materials to reduce the demand for the particular material. The construction aggregates are to be tested for green sand mould making application along with silica sand and it possible to replace silica sand to some proportion or fullness in the sand mould. Further silica free sand, tailing sand, chromite sand, olivine sand, alumina and other waste powders like fly ash, tamarind powder, coconut shell powder can be mixed in suitable proportion with different combination along with suitable binders and additives to create a standard AFS specimen and to check the properties like, green and dry compression strengths, permeability, shatter index, etc., If the suitable combination of these alternative sources is found, then casting is
produced from standard material and tests to be carried out to confirm the suitability of this alternative material for mould and core making.

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