Silicate bonded moulding sand

This article aims to show the advantages and disadvantages of this method, as well as the technical requirements for reintroducing the silicate process in today's modern foundry.

Introduction

Silicate binders, also commonly known as water glass, are probably the oldest core and mould binders used in the foundry industry. The water glass method in combination with CO_2 gas or esters as a liquid hardener has been used in iron, steel and non-ferrous foundries since the 1950's, however, the introduction of organic binders in the 1970's resulted in a marked drop in the demand for silicate binders.

More recent health and safety guidelines and increasing environmental legislation has led to a renaissance of this inorganic and odourless class of foundry binding agent.

Background

Water glass is a silicic acid salt and used in aqueous solutions containing different amounts of Na_2O and SiO_2 (modulus) as a binding agent for sand.

This obviously offers the advantage that all the toxic emissions originating from organic binding agents during the casting process can be largely, and in some cases completely, avoided. The production of moulds and cores using esters or CO_2 gas can also be described as odour-free, meaning that water glass and silicate binders can be classified as environmentally friendly binding agents, however, the general disadvantage of inorganic binders is their break down characteristics after casting and the reclaimability of the residual sand.

Water glass consists of a solution of alkali silicates (Na, K, Li), silicic acid and water. For reasons of price, as a rule almost 100% sodium silicates are used. Adding other alkali silicates influences its behaviour in terms of stability, break down and viscosity (figure 1).

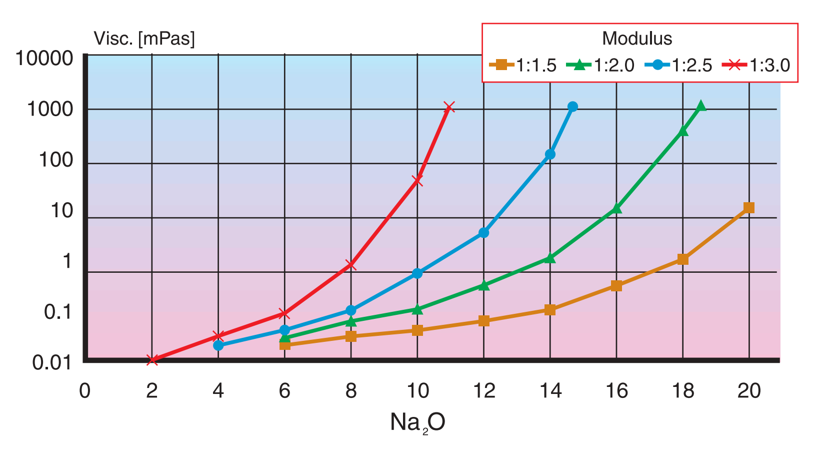


Figure 1 Viscosity dependence of sodium-silicate solutions

The ratio of Na_2O:SiO_2 is shown as a modulus:
Example: Modulus 2.4 => 1 Na_2O part : 2.4 parts SiO_2

All sodium-silicate solutions polymerise when the pH value falls below 10. When organic esters are used, the alkalinity of the silicate solution is consumed by hydrolysis over a longer period of time. The gel forms an adhesive bond with the surrounding sand.

Factors influencing the properties of sodium-silicate binders

1. Increasing concentration (solid content) of sodium water glass has the following effects:

☐ Increased viscosity	binder
☐ Shorter time for processing	moulded material
☐ Poorer flowability	
☐ Reduction of immediate stability	core
☐ Reduced overhardening risk	
☐ Increased final stability	
☐ Longer storage life	
☐ Increased resistance to moisture	
☐ Deterioration of core breakdown	

2. Increasing modulus of the binder has the following effects:

☐ Increased viscosity (with same solid content)	binder
☐ Shorter time for processing	moulded material
☐ Poorer flowability	
☐ Improvement of immediate stability	core
☐ Increased overhardening risk	
☐ Reduction of post-hardening	
☐ Reduced final stability	
☐ Shorter storage life	
☐ Lower resistance to moisture	
☐ Deterioration of core breakdown	

3. Increasing additives in the binder have the following effects:

☐ Lower viscosity	binder
☐ Lower tendency to adhesion	moulded material
☐ Improved flowability	
☐ Improvement of immediate stability	core
☐ Improved final stability	
☐ Longer storage life	
☐ Lower moisture resistance	
☐ Improved core breakdown	

4. In addition to chemical transformation, viscosity increases considerably as a result of modulus change (partial neutralisation). Furthermore, some of the existing moisture is chemically bonded and a further part transported out of the core with the non-transformed CO_2.

The cross-linking effect is created by the dehydrating of Na_2SiO_3.

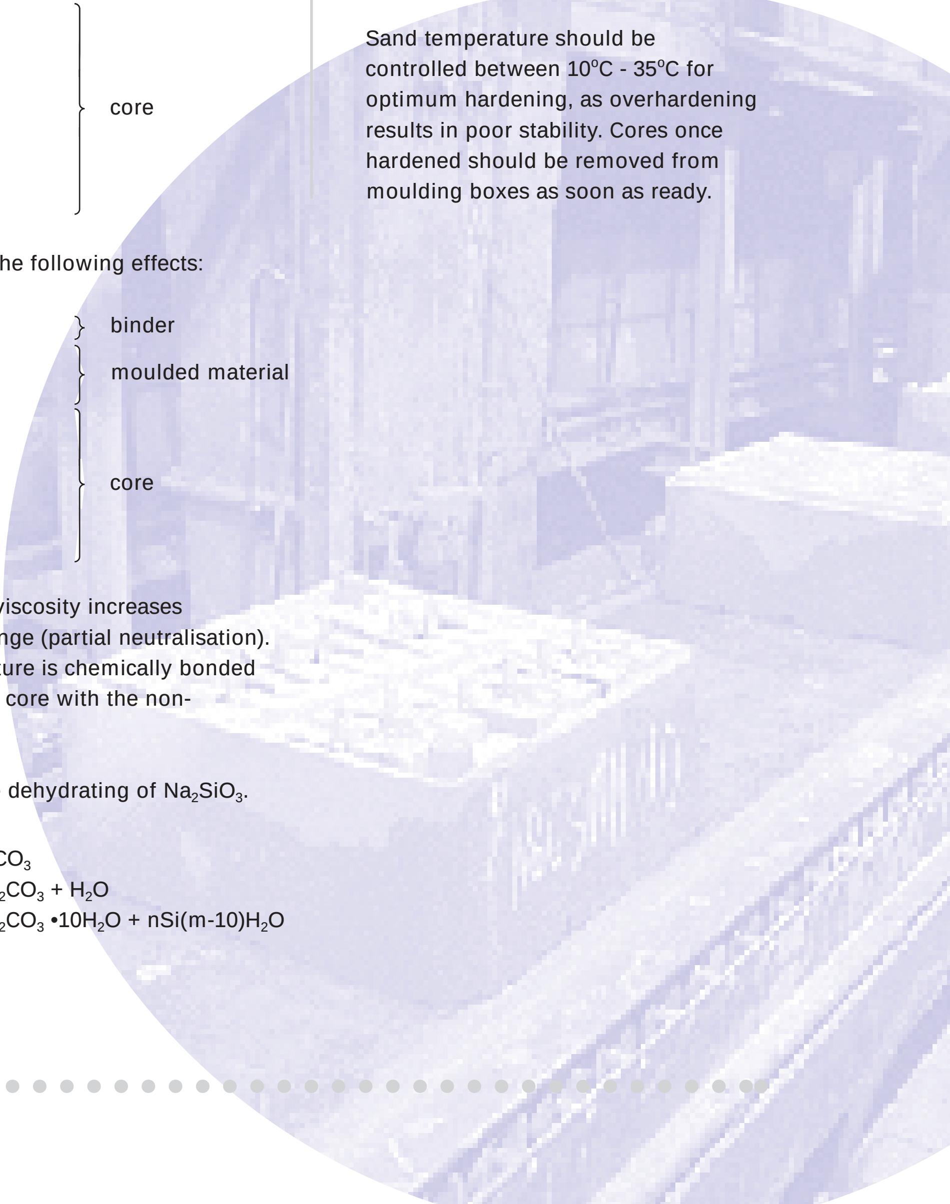
$$
\begin{aligned}
CO_2 + H_2O &\longrightarrow H_2CO_3 \\
Na_2O + H_2CO_3 &\longrightarrow Na_2CO_3 + H_2O \\
Na_2O \bullet nSiO_2 + mH_2O + CO_2 &\longrightarrow Na_2CO_3 \bullet 10H_2O + nSi(m\text{-}10)H_2O
\end{aligned}
$$

5. The temperature of the moulded material and of the hardening gas influences the speed of hardening. A saving of up to 30% CO_2 gas is possible by means of pre-heating.

6. The choice of the type of hardener not the quantity added determines the speed of hardening

7. Sand type
The following sands are suitable for processing with silicate binders: zircon, chromite, olivine, Chamotte and silica sand as well as mixtures of these. The sand should be dry and not contain high proportions of fines as this reduces stability and increases adhesion. The sand should ideally be fairly pure, i.e. not contaminated by chalk or cement and be between 65-75 AFS.

Sand temperature should be controlled between 10°C - 35°C for optimum hardening, as overhardening results in poor stability. Cores once hardened should be removed from moulding boxes as soon as ready.



The influence of water-glass bonded sand in other core and moulding processes:

- **bentonite-bonded moulding sand:**
  quality loss of > 15% as a result of over- activation and grain coarsening
- **resin-bonded acid-hardening moulding materials:**
  delay of hardening or neutralisation of the hardener.
- **cold box method:**
  destruction of the isocyanate and/or acceleration of the catalyst as a result of a change in pH

Dehydrating

The dehydrating process depends above all on the ratio (modulus) and the temperature: the higher the ratio and the temperature, the faster the water separates.

In other words, the actual hardening process includes both a chemical and a physical phase. The sodium silicate precipitates by means of changing the pH and subsequently gaining more stability as a result of drying.

This also explains the break down properties when used for iron and steel casting. By contrast, stabilities are at their lowest when molten metals (up to 800°C) are used (figure 2).

A further positive effect of water glass in the field of steel casting is the cooling effect that can be achieved, which in many cases makes the use of special sands, such as chromite or zircon sand, superfluous. Accordingly, one of the main markets for water glass is the manufacture of steel castings.

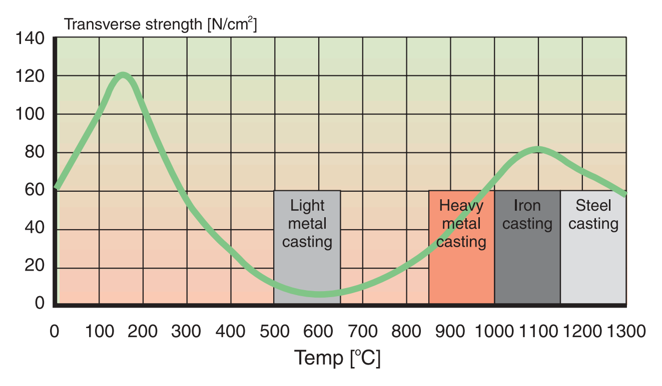


Figure 2 Transverse strength of water-glass bonded sand in relation to the temperature

Reclaiming water-glass bonded sand

The inorganic, non-combustible binding agent leads to an accumulation of sodium carbonate (soda) and sodium silicate in the spent sand. Whilst providing excellent hot strength, these substances will, if present in sufficient amounts, cement the sand grains together after casting and make de-coring and reclaim difficult. The refractoriness of the reclaimed sand is also affected. When silicate binders are used with silica sand they can actually react with sand itself, lowering its temperature resistance and causing burn-on and penetration.

This means that the removal of residual binder is a crucial factor in the re-usability of spent sand. Various techniques, such as air-jet, fluid-bed and grinding are sufficiently well known and documented.

The following describes a new method, which has already been tested in practice with considerable success.

Water-glass applications

Scana Steel Stavanger is Norway's largest steel foundry and specialises in wear parts for crushers and grinders, castings for use on offshore oil rigs and propeller blades. Scana uses olivine sand and Foseco silicate binder system for both cores and moulds; new sand was used for cores and as facing in moulds, whilst a mixture of spent and new sand was used as backing sand in moulds.

Economic factors obliged Scana to consider ways of reducing their specific sand consumption and this meant increasing the proportion of reclaimed sand used by the foundry. With this in mind, Scana decided to investigate technology developed and patented by Noram Technology Ltd. The Noram Nordic area licensee, Noramtek AS made a pilot plant available for the purpose and this has been operating at Scana since April 2002 in a project supported by the Norwegian State's Industrial Development Fund, SND.

Project goals

The project had the goal of reducing the Scana total variable production cost by at least 10%, as follows:

- A reduction of 50% in the Scana specific sand consumption
- A reduction of 10% in the Scana specific binder consumption
- A reduction of 10% in fettling costs as measured by consumption of welding rod.

Installation

The Scana previous sand reclamation set-up entailed separating sand from cast goods by mechanical shake-out, after which the lumps of sand were crushed and sieved and the resulting product cooled and fines removed in a fluid bed cooler/classifier.

The Noram plant included a controlled energy attrition unit (the Cubifier) and a multifraction crossflow air classifier. Noramtek installed this pilot plant in parallel to the existing set-up, and in order to save space and minimise installation costs it was decided to place the two new units on either side of the existing cooler/classifier. Had the results of the new process not been satisfactory, it would then have been a simple matter to revert to the previous reclaim technique.

After being conveyed through the cooler/classifier, the sand was then moved pneumatically to the holding silo used to feed the Noramtek classifier. It was planned to operate the latter at 5-7tph.

Operating experience

The plant has operated fully automatically and continuously since early summer, with occasional stoppages due mainly to problems with transportation equipment. The latter was in part the result of a decision taken to increase throughput, and it was shown that the plant could in fact be run with excellent results at 15tph but this overloaded both the conveyors and particularly the cooler/classifier.

Even though a number of attempts have been made to improve throughput in the cooler/classifier, its capacity is nonetheless severely limited by the level of fines (5-8% below 0.1mm) created in the attrition unit. This limited the throughput of the plant to 7tph during the trial period. The plant has since been modified to 10tph and now processes almost all of the Scana sand.

Quality control

Regular sieve analysis was carried out on sand entering and leaving the attrition unit and classified sand re-used by the foundry, both after the classifier and at the point of mixing, i.e. after pneumatic transport. These were compared to similar samples taken before the plant was installed. Sodium-analysis was also performed on the classified sand after Scana had purchased a Sodium-meter for the purpose.

Sand quality

Scana have found a considerable improvement in the quality of sand treated in the new plant, both in terms of reproducibility and casting properties. Bench time was considerably extended compared to the previous spent sand and better even than that which typifies new sand. This led to a decision to replace both facing and backing sand with a unit sand produced in the Noramtek plant.

Comparison of results and goals

Table 1 shows the main achievements following the installation of Noramtek plant:

ITEM	GOAL	ACHIEVED
Net sand consumption (1)	50%	70%
Binder consumption	10%	20%
Scrap moulds due to sand quality	None	None
Fettling costs	10%	Awaiting final measurement
Chromite sand consumption	20%	Not carried out (2)
Air quality	Particulates -20%	Not measured

Table 1

1 Scana can now re-use 80-85% of their sand compared to 30% before installation of the plant

2 Scana chromite sand consumption is only 200tpa and thus too small to make separate reclaim practicable.

Estimates of total savings

a) Sand
Scana use an 85/15 used/new sand ratio in the unit sand for all applications this reduces net sand consumption by nearly 80%. A programme for further optimisation aims at using a 92/8 unit sand for all purposes.

b) Binder
Scana uses a binder addition of 3% CARSIL* 2000 and 10.5% on binder of catalyst. A reduction to 2.5% translates therefore into savings of about 20%/yr. In other words the consumption of originally 400t/y CARSIL 2000 were reduced to 320t/y AMASILIC* 110, a product developed during the project period.

The unit sand stability and reproducibility has encouraged Scana to examine the possibility of achieving further savings by purchasing a new main mixer. It is considered likely that this will allow binder consumption to be reduced to 2.25% or less.

c) Scrap moulds
Scrap moulds cannot be reclaimed. Scana has not experienced a single scrap mould since installing the Noramtek plant and calculations suggest that this alone saves the company about US$2,500 per month, or roughly US$30,000 per annum.

Total savings

Scana have demonstrated that a full-scale Noramtek plant has a payback time of less than 9 months.

The net effect of an installation will however be greater, since the plant improves Scana manufacturing efficiency too, allowing net production to be increased for the same manning levels. Furthermore, an investment in new mixing equipment will allow the proportion of new sand in unit sand to be reduced still further for the same residual binder content.

The plant also has the advantage of making Scana less sensitive to stricter environmental requirements and it is likely that all secondary products will, since they are available in ready-classified form, be usable in other applications, e.g. asphalt, fertiliser and as sand in dryblend mortars. This will be the subject of a separate development programme.

Noram technology

Noram patented technology combines a new concept in particle classification with a patented controlled energy attrition unit specially designed for foundry needs (figure 3)

Figure 3 Noram crossflow classifier

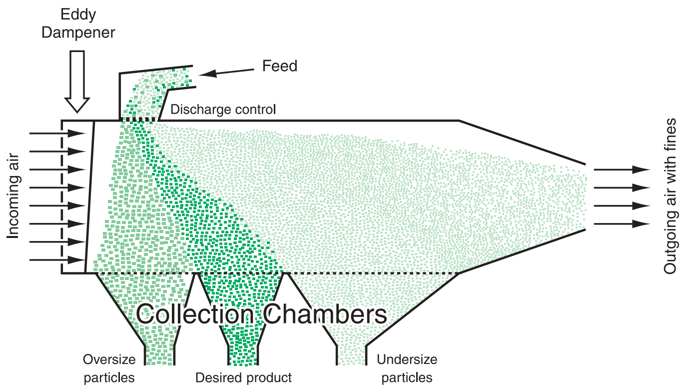


Figure 4 Operating principles of the Noram crossflow classifier

The Noram crossflow classifier (figures 3 and 4) has been specially designed by Particle and Coating Technologies Inc. for use in manufacturing and reclaiming foundry sand. The classifier causes an eddy free air stream to differentiate particles according to their drag per unit of mass. This not only removes dust, binder flakes and sand fragments from useful sand but also allows the foundry to select the upper and lower cut-off points for an optimal size distribution of the reclaimed sand and even make separate grades of sand for moulds and cores. This approach is particularly useful in the reclamation of silicate bonded sand, where much of the residual binder is stripped off in the cubification stage (see below) as fairly large flakes that can be difficult to separate out effectively by conventional methods such as fluid bed classification.

The Attrition Unit (“cubifier”)

The patented Barmac attrition unit combines impact and grain rounding forces and controls them independently of one another in a unique cubifying action. This is illustrated in the cut-out (figure 5). The Barmac unit used in the Noram process has been specially designed to maximise the frequency of glancing collisions between the particles. This type of collision can take place at high energy input levels so that binder residues are stripped away and surface irregularities broken off without the grains being crushed. This is especially valuable when reclaiming sand where the residual binder remains as an elastic film on the sand surface, e.g. silicates, since this requires considerable attrition energy.

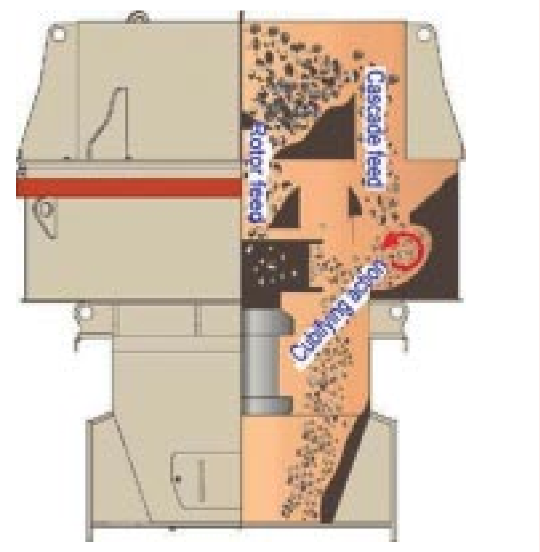


Figure 5 Attrition Unit (cubifier)

Careful control of cubification energy and optimal use of classified products, can yield recycle rates of 93% or more for chemically bonded sand.

Noram technology

1. lower binder consumption
- optimising particle shape and size distribution improves packing characteristics and reduces fines content. This can lead to savings of as much as 10-20% in specific binder use.

2. reduced sand consumption
- careful control of cubification energy and optimal use of classified products, can yield recycle rates of 95% or more for chemically bonded sand.

- under certain conditions, a Noram plant can differentiate between quartz and other sand, allowing separate recycle of each

3. minimal dumpsite costs
- waste sand is also classified and can meet construction industry standards for filler, fine aggregate etc.

4. lower unit sand costs
- The Noram patent describes how a Noram-process recycle plant can also be used to upgrade low cost sand from local sources to foundry quality products.

5. increased sand recycle
- reclaimed furane-bonded sand can be used as new sand with phenol-urethane binders

6. lower fettling costs
- castings made with sand processed in a Noram plant have superior surface finish and are less prone to finning.

7. lower scrap rates
- reductions in scrap rates of as much as 25% have been achieved following installation of a Noram plant

Environmental issues

- a Noram plant acts as a ventilation unit, removing dust from foundry air.
- sand recycled through a Noram plant is less dusty and has a lower loss on ignition than when processed conventionally
- recycled sand is less angular and less prone to create dust during internal transport
- lower binder consumption means lower levels of volatile organic substances in foundry air
- for furane-bonded sand, lower loss on ignition means reduced levels of sulphur-containing gas in the foundry.
- A Noram plant can make it easier for foundries to change to cost effective quartz-free sand.

FOSECO Silicate binder product range

BRAND	APPLICATION	PROPERTIES
SOLOSIL*	CO_2 Gas set – Core making	These products reflecting different demands on strength, break down and mixed sand flowability requirements
AMASILIC GS		
NUCLEPON*		
CARSIL	Catalysed Self setting – mould making	These systems fulfil highest demands on reclaiming, mixed sand bench-life and final strength properties
AMASILIC		

A number of steel foundries in Spain have already discovered the attractiveness of the FOSECO sodium silicate product range for their sand systems. Here even flask less fast loop lines with strip times down to 5 minutes and reclaim sand ratio up to 90% are producing castings in a range between 5kg to 15 ton. Examples are seen in figures 6 – 9.

Figure 6 Facing with new sand. Back-up with 100% silicate reclaimed sand in a flaskless application

Figure 7 Facing (30%) new sand. Backing (70%) reclaimed sand with continuous mixer in one step

Figure 8 Mould filling of large flasks using continuous mixers

Figure 9 Odour and emission free work environment in a silicate foundry

Summary

With the availability of new sand reclaiming techniques, combined with the latest FOSECO silicate binder developments, environmental problems in the form of emissions and odours can be drastically reduced. Furthermore, the new silicates enable binder reductions leading to improved break down properties and therefore to better productivity rates then ever seen with inorganic binder systems.