CASE STUDY

BORREGAARD BIOPOLYMERS INCREASE TILE STRENGTH

Borregaard

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INTRODUCTION

Tile quality is directly related to the raw materials used in the clay body. Reliable, high quality raw materials combined with consistent processes normally result in good quality fired ware.

Unfortunately, in the real world, raw materials vary in quality and consistency. Variations often occur in properties such as particle size, fired colour, carbon content, etc. Moreover, pricing and fluctuations in availability of high-quality raw materials can compromise the competitiveness of your product.

Tile manufacturers look for alternatives that ensure the highest quality of their final product. A viable alternative is the use of additives which upgrade the properties of the raw materials to the required level to achieve optimal production. In fact, additives have become an essential component of tile formulations. Added in small amounts, these chemical components are capable of improving the physicochemical characteristics and rheological properties of the raw materials across the production steps.

Additives can be classified according to their function: deflocculants, which are added to improve the rheological properties of the clay slurry; and binders, which are included in the formulation to strengthen the mechanical properties of the tile. They can also be classified according to their chemical composition as either inorganic or organic.

Among the inorganic additives we can find silicates, typically sodium silicate used mainly as deflocculants. It is also common to add magnesium alumina silicate, which to some extent increases the green and dry strength of the tile. Bentonites are also added with this same effect.

Organic additives are usually polar polymers of different chain lengths. The presence of polar groups in the chemical structure is required to form tridimensional bonds with the raw material particles.

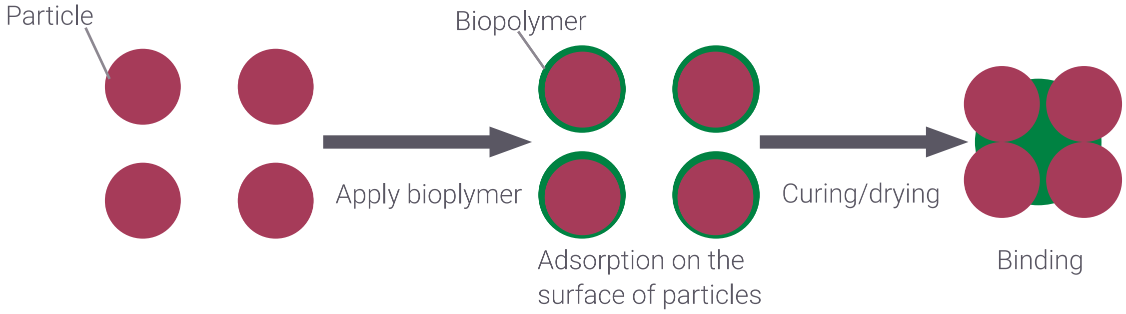


Figure 1: Mechanism for binding.

Organic additives are further divided into synthetic and natural additives. Synthetic additives are frequently oil-derivates, whereas natural additives are produced from renewable sources, for example, biopolymers produced from wood, either cellulose or lignin based.

Modified lignin based biopolymers are excellent additives in the decorative ceramic industry. They are primarily used as binders to increase the mechanical resistance of tiles. They are capable of adsorbing onto the particle surfaces of the raw materials and binding them together as the tiles dry.

Tests in our own Ceramic Lab show that choosing the correct biopolymer is key to optimal binding performance.

RHEOLOGY AND STRENGTH TESTS

We have run rheology and flexural strength tests in our Ceramic Lab. Here we show two examples using two white body clay mixes.

The first body clay mix was used to compare four of Borregaard's biopolymers. The addition rate of the liquid additive was adjusted so the active component (dry biopolymer) was precisely 0.5%.

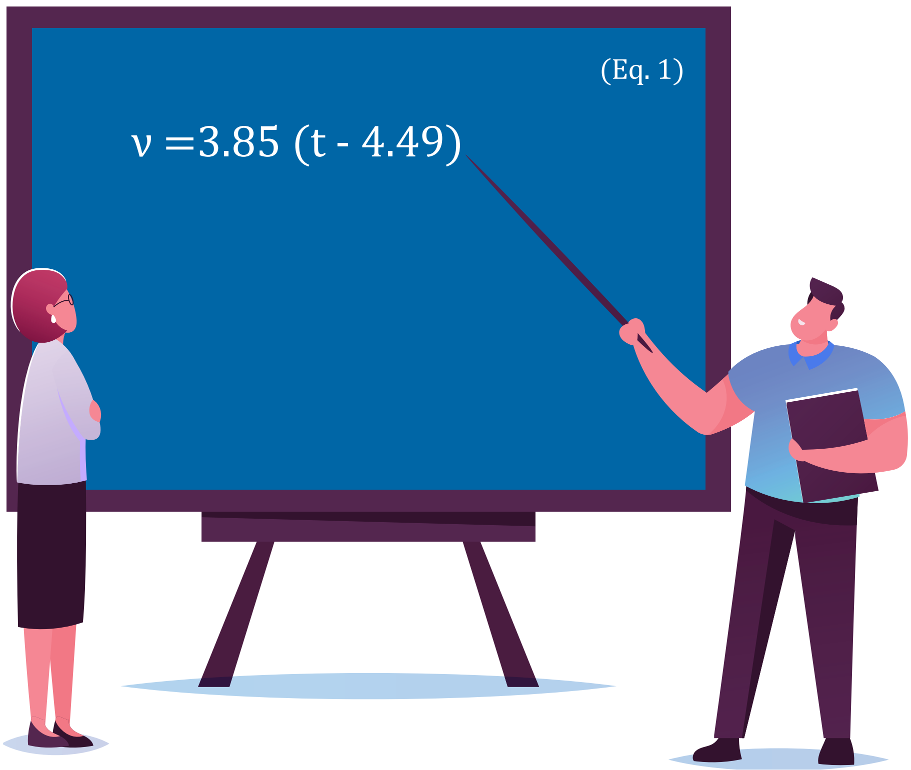
The second body clay mix was used to compare the performance of three biopolymers at the same liquid dosage, 0.5%. The solids content of biopolymer 1 was 50%, and the solids content of the other biopolymers was 45%.

VISCOSITY BEHAVIOUR

The viscosity was determined following ASTM D1200-10, which is the standard test method for viscosity using Ford viscosity cups. Ford Cup number 4 was used for all samples.

Slurries including the biopolymers were vigorously stirred for 10 minutes at 300 rpm. They were allowed to stand undisturbed for another 10 minutes at room temperature. The Ford Cup was filled with the slurry. The time (t) for the material to flow through the orifice was measured in seconds. The values can be converted to kinematic viscosity (ν) in centistokes (cSt) using eq. 1:

Figure 2: Ford Cup.



[1] $1\ cSt = 1\ mm^2{\cdot}s^{-1} = 10^{-6}\ m^2{\cdot}s^{-1}$.

The results are presented in Figure 3 and Figure 4.

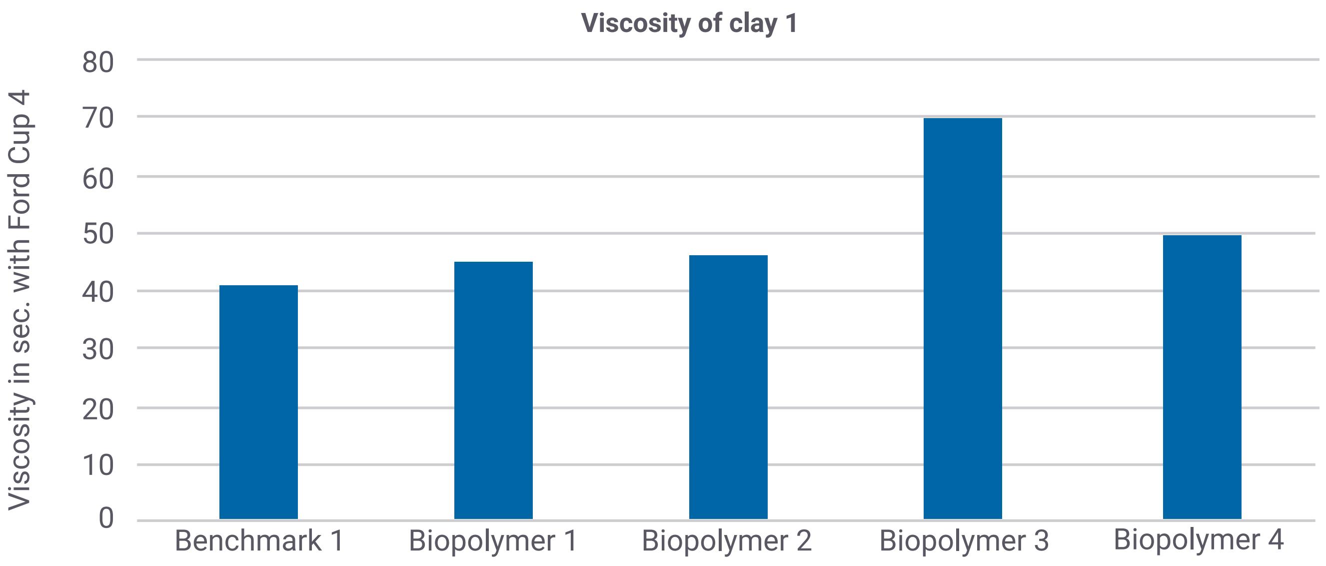


Figure 3: Viscosity of clay 1 slurry with different biopolymers.

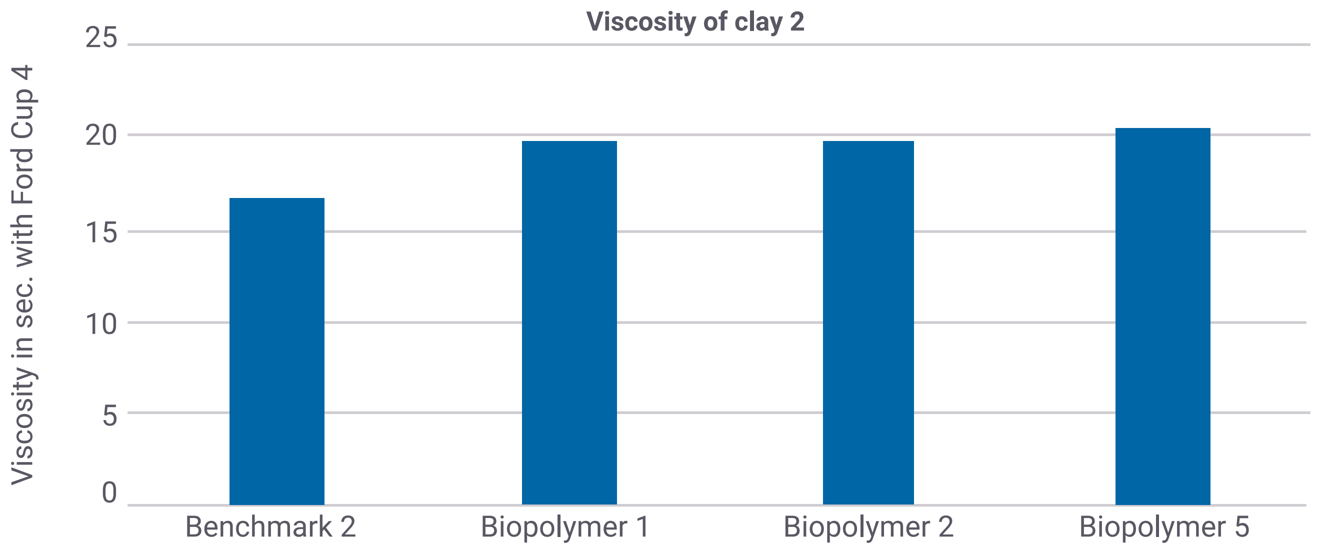


Figure 4. Viscosity of clay 2 slurry with different biopolymers.

The results show that all the biopolymer binders in the study can be used in this body without a significant impact on the rheology of the slurry, except for biopolymer 3.

STRENGTH INCREASE

The mechanical resistance, or Module of Rupture (MOR) of the tiles was determined following the three-point bending flexural test.

Six tiles of each composition were pressed at 50 bars (368 kg/cm^2). Pressure was adjusted to achieve the same apparent density in all the compositions. The tile weights and dimensions were measured to check tile density and moisture of the powder. Mechanical strength was measured using a Nannetti Flexometer (Mod. CC-96-2006) shown in Figure 5.

Figure 5. a Nannetti Flexometer (Mod. CC-96-2006).

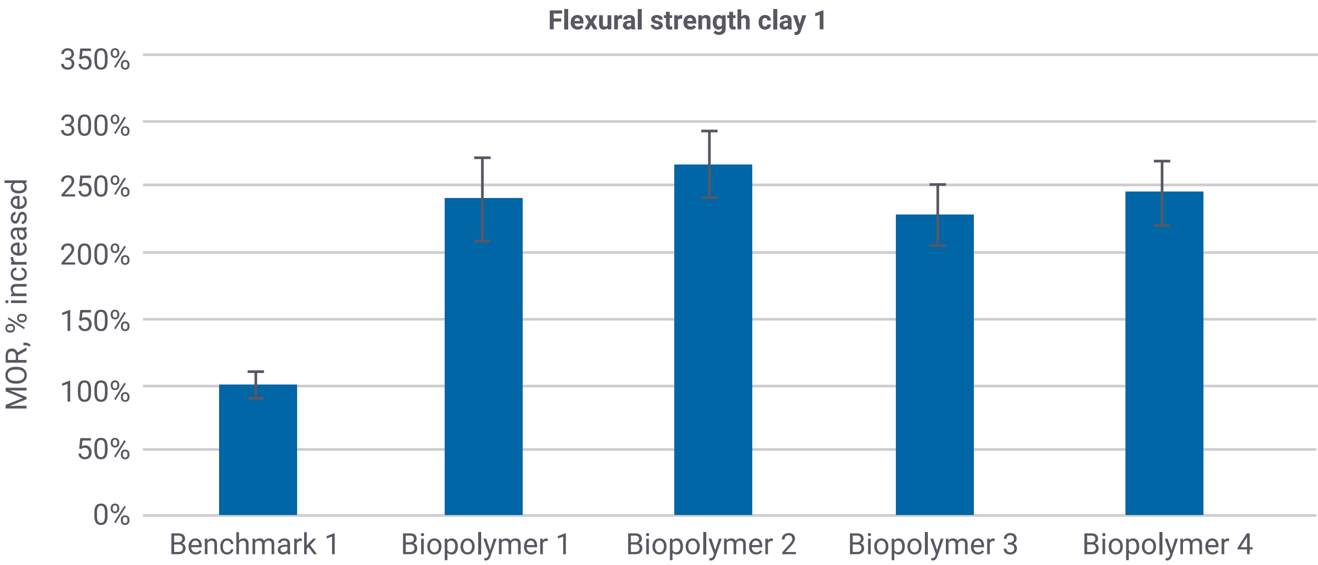


Figure 6. Flexural strength increase with respect to the benchmark clay 1.

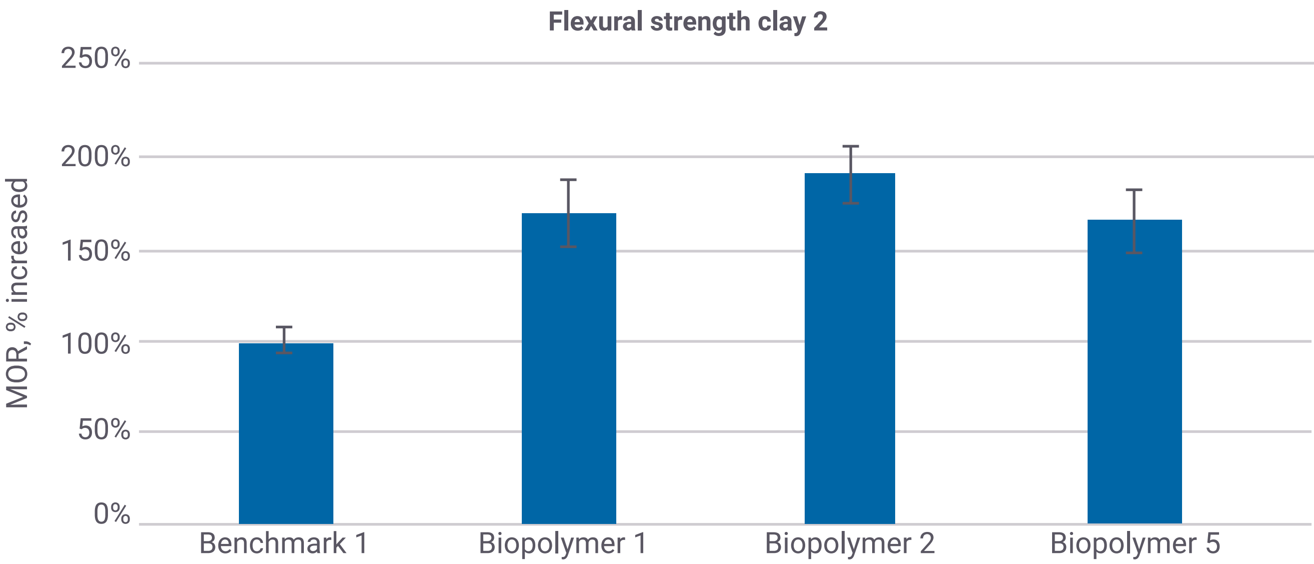


Figure 7. Flexural strength increase with respect to the benchmark clay 2.

Figures 6 and 7 show how the flexural strength increases with the addition of biopolymers for tiles which have been dried at 105 °C.

It is clear that our biopolymers strengthen the tiles making them more resistant to impacts encountered during transportation on roller conveyors, and the engobe, glazing and decoration applications. A dosage of 1% liquid (approximately 0.5% solids) more than doubles the strength. This results in lower breakage during production. Moreover, the increase in MOR opens the door for production of larger and thinner tiles, which could be very interesting in the production of big slabs.

If we review the formula to determine MOR for rectangular samples under a load in a three-point bending setup:

$$\mathrm{MOR} = \frac{3\,F\,L}{2\,w\,t} \qquad \text{(Eq.1)}$$

Where F is the force applied to the tile, and L, w, t are the length, width, and thickness, respectively. With addition of a Borregaard biopolymeric binder it is possible to increase the length and/or reduce the thickness of the slab without compromising the mechanical strength.

We also show here that not all biopolymers have the same performance. There is some variability in strength increase. The additives tested here have different physico-chemical properties which impact their performance. For example, biopolymer 3 did not increase the strength of clay 1 as much as the other products. However, it was also the product which had the highest impact on the viscosity.

CONFIDENCE INTERVAL

The error in the strength and dry density average was calculated following a standard UNE 66040, equivalent with International Standard ISO 2602:1980. The outliers were detected following Grubb's test for outliers, which is the recommended method according to international standards. You can learn more about this here.

CONCLUSIONS

Borregaard has a large portfolio of additives. Selecting the best biopolymer for your ceramics is key to improving the mechanical properties of the tiles without compromising the rheology of the slurry.

We have shown that our biopolymers are capable of significantly increasing the strength of dry tiles. Dosage of just 0.5% of a suitable liquid additive is enough to make the tiles twice as resistant to flexural stress with negligible effect on the viscosity of the slurry.

It is important to understand that not all biopolymers are the same. Borregaard offer a wide range of products with different physical and chemical properties. Our R&D department has developed biopolymers with optimal performance as binders without compromising the rheology of the clay slurry. Our ceramics technical experts can recommend the best product for your specific needs.

ABOUT US

Borregaard operates the world's most advanced and sustainable biorefinery. By using natural, sustainable raw materials, Borregaard produce advanced and environmentally friendly biochemicals and biomaterials that replace oil-based products. Our world-wide network of production facilities and sales offices assures the very best local service and competence where you need it. For us, providing our customers with the most dedicated technical assistance is key. Therefore, the company invests considerable resources in research and development. We continuously strive to develop wood based renewable products for new applications, and through that we contribute to delivering present alternatives to oil based synthetic products in a wide variety of industries.

If you need more information please contact us:

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