Inorganic Pigments

Technical Information
Competence Center Construction

Edition: May 2002
Replaces edition: July 1998

Inorganic Bayferrox® Pigments for Coloring Sand-Lime Bricks

Introduction

Sand-lime bricks, which have been produced since the turn of the century, have become a very popular building material in many parts of the world. As far as Europe is concerned, it is mainly in Germany, The Netherlands, England, Switzerland, Denmark, and Sweden that large quantities of sand-lime bricks are being produced. A considerable proportion of the total production is accounted for by hollow blocks and perforated blocks, which are used for load-bearing exterior or division masonry. Sand-lime bricks - appropriate quality provided - are however also highly suitable to be used as solid bricks in fair-faced masonry. Beside the solid sand-lime bricks with their smooth surface, split blocks with quarry-stone-like surface are also frequently used for the designing of fair-faced masonry. Fair-faced masonry from smooth and, still more, from split sand-lime stones have special architectural effect.

This effect is still increased by the possibility of using colored sand-lime bricks. Suitable synthetic color pigments are available for this purpose today and give the bricks a pleasant permanent coloration. The designing of fair-faced masonry with colored sand-lime bricks, which is being more or less practised at some places, underlines the versatile possibilities given by this material.

Pigments

In accordance with all investigations carried out so far, permanent coloration of sand-lime bricks can only be achieved if the whole sand-lime mass is colored with suitable pigments. Coloration by surface coating, no matter on what basis, cannot replace the durability of integral coloration; besides, its hides the characteristic structure of the sand-lime brick.

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The color pigments are required to meet the following demands:

- Lime resistance
- Resistance to the temperatures occurring when the bricks are cured
- Light and weather resistance because the colored sand-lime bricks are to retain their color also when used for exterior masonry

The investigations have shown that beside organic pigments, which are unsuitable either because of their poor alkali resistance or because of their insufficient light and weather stability, also a number of inorganic pigments cannot be used for the coloration of sand-lime bricks.

The following inorganic Bayferrox® pigments are suitable for use in sand-lime bricks:

red	all Bayferrox® red grades
yellow	all Bayferrox®- yellow grades, Colortherm 3950
brown*	Bayferrox® 645 T
black	Bayferrox® 303 T
green	Chrome Oxide Green GX, GN

* A variety of brown shades can be created by combining Bayferrox® red and yellow with Bayferrox® 303 T

As can be seen, the majority of Bayferrox® blacks and browns are not suited to the intended application. The reason is that by oxidation during the steam curing process, the color shade of the blacks, except Bayferrox® 303 T, is shifted towards brownish red. The same applies to the browns except Bayferrox® 645 T since these are mixtures of Bayferrox red and yellow and/or black. The Bayferrox® yellows undergo, like the blacks, a change towards red when processed at normal temperatures of > 180 °C, but do remain stable during steam curing because a special process is employed: even if steam curing is carried out at 16 bar (204 °C), the chemically bound water will not be split off. The yellows may thus unhesitatingly be used.

Pigment addition in the production of sand-lime bricks

The production of colored sand-lime bricks raises the question where to add the pigment in the course of the manufacturing process. This depends on the production methods prevailing in the plant. Basically, continuous and batch-wise mixing of the sand-lime mass are practiced. The general tendency will be to add the pigment, whenever possible, following the reactor in order to keep the latter free from the pigment. This, however, is only possible if intensive incorporation of the pigment by a suitable after-mixer is ensured. If the mixing effect is insufficient, the fine-particle pigments cannot be perfectly distributed in the relatively dry sand-lime mix: their high tinting strength is not fully utilized, and disturbing pigment bulking may be experienced.

When the batchwise method is applied, it is advisable to use a high-speed compulsory-type mixer if the pigment is to be added following the reactor. Additionally, the intensive aftermixing in known to improve the quality of the bricks.

In continuous operation, where in most cases double-shaft mixers are used, good distribution of the pigment in the after-mixer cannot be achieved. When working continuously, the pigment should therefore already be added to the pre-mixer. Thus the pigment undergoes a double mixing process; in addition, the staying of the sand-lime mass in the reactor ensures a better distribution of the pigment in the after-mixer. Because of the relatively poor flow properties of the powder pigments, the continuous pigment metering causes difficulties if exacting demands are made on precision. Both precise continuous addition of the powder pigment or of a pigment slurry and good incorporation into the mix can be obtained by using today's dosing and dispersing technology. When the pigment is added in the form of a suspension, the level of pigmentation is however limited because only a restricted pigment amount can be added to adjust the press moisture.

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Granulated pigments like Bayferrox® 110 G are not recommended for use in sand-lime bricks. In the fine sand-lime mix, in contrast to other building materials, e.g. concrete pavers, the granules take much more time and require much more energy to become distributed; and even if this problem is solved, others may arise. If the use of granulated pigments, which do offer considerable advantages, is taken into consideration, then preliminary trials under the prevailing manufacturing conditions are indispensable.

The color shade as a function of pigment concentration and of other factors

a) Quantity of pigment

The pigment proportion is preferably calculated in per cent by weight related to the overall mix of sand and lime, no matter whether the pigment is added as dry powder or as aqueous suspension. Since the sand-lime mix as such has a light natural color, the production of colored bricks from delicate pastel shades to deep colors is possible without any difficulty; only deep brick red shades cannot be achieved.

The following may serve as a rough guide as to the pigment quantities required (percentage figures calculated on overall mix):

pastel shades:	0.2 - 0.5 %	pigment
medium shades:	0.5 - 1 %	pigment
deep shades:	1 - 2 %	pigment

In analogy to the coloration of other building materials like concrete, plaster, mortar, and others, we find that also in the coloring of sand-lime bricks a higher pigment addition does not necessarily mean a deeper color shade: there is a limit of saturation. Fig. 1 shows the increase in color intensity as a function of pigment addition using Bayferrox® 920 (yellow) as an example. The colorimetric measurements were taken on pigmented sand-lime brick samples which had been steam-cured at 8 bar for 8 hours. It is obvious that between 0 and 1 % the increase in color depth is considerably greater than between 1 and 2 % of pigment.

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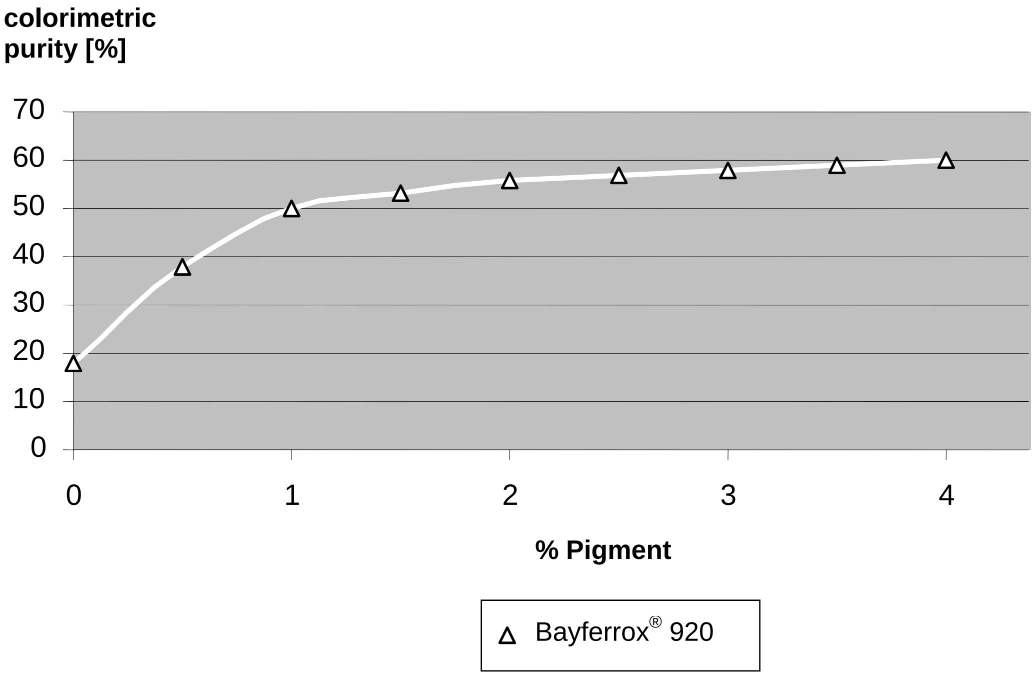

**Fig. 1: Sand-lime bricks pigmented with Bayferrox® 920
Color intensity as a function of pigment concentration**

b) Color of the raw materials

The color of the sand-lime bricks is substantially determined by the natural color of the sand, because the lime - leaving a few exceptions out of account - has a white color subject to negligible variations. Since the pigment is fixed in the binder and since the binder, as shown by microscopic studies, fails to completely surround the sand grains, it is obvious that the natural color of the sand greatly influences the resulting color shade. The lower the pigment addition the greater of course this influence. Generally, the sands used for the production of sand-lime bricks differ by a more or less intensive brown shade, which is chiefly determined by their content of iron oxide. The darker the sand's natural color the more marked the color shade the brick undergoes: a light yellow will shift towards a darker, dirtier yellow, a red towards bluish red, and a green towards a dirtier blue green. It should therefore be realized that the production of uniformly colored sand-lime bricks over a prolonged period of time may be connected with certain difficulties because the sands - even those from one and the same pit - do not always have the same colors. So the sand's natural color is, besides other sand characteristics, an important factor to be considered in the production of sand-lime bricks. On the other hand variations in the color shade, provided they are not too marked, may even have a favorable influence on the appearance of fair-faced masonry.

c) Lime content

Basically, it is to be expected that the color shade is lightened with increasing lime contents in the mix, equal quantity of pigment provided. Appropriate tests have however shown that production-related fluctuations of the lime addition have no noticeable influence on the finished bricks unless the differences are relatively marked: ±1 %, for instance, has virtually no effect on the resulting color shade.

d) Curing conditions

On the other hand, the influence the curing conditions have on the color shade are considerably greater. According to our experiments, which were carried out between a range of 8 and 16 bar, the color grows distinctly paler as the steam pressure rises. The product of curing time and steam pressure was in each case 64 bar x hours, the customary curing conditions being either 8 hours at 8 bar or 4 hours at 16 bar. With the same quantity of pigment added, the shades of the bricks steam-cured at 16 bar proved distinctly paler than those of bricks steam-cured at 8 bar. A reaction between the lime and the pigment must be ruled out. This means the lightening effect is due to the formation of different reaction products or binder quantities when the lime reacts with the silicic acid of the sand. This lightening effect can also be observed in unpigmented bricks, as could be demonstrated by lightness measurements on bricks produced under the stated conditions. The phenomenon described here cannot only be observed in laboratory tests, but can also be reproduced in trials on production scale. Consequently, colored sand-lime bricks should preferably be steam-cured at 8 bar in order to achieve a maximum of color intensity with a given quantity of pigment.

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Strength properties of pigmented sand-lime bricks

Sand-lime brick manufacturers are interested to know whether the strength of their bricks may be influenced by the addition of pigments. To answer that question we produced prisms of sand-lime bricks (16 x 4 x 4 cm) which contained rising quantities of pigment of up to 4 % b. w. calculated on total mix - a concentration that will hardly be realized in practice. The prisms were steam-cured at 8 bar for 8 hours; after 24 hours we tested their compressive strength and flexural bending strength. The results are demonstrated in Figures 2 and 3 for the pigments Bayferrox® 110 (red), Bayferrox® 920 (yellow) and Chrome Oxide Green GN. There is obviously no decrease in strength, even with extremely high pigment additions.

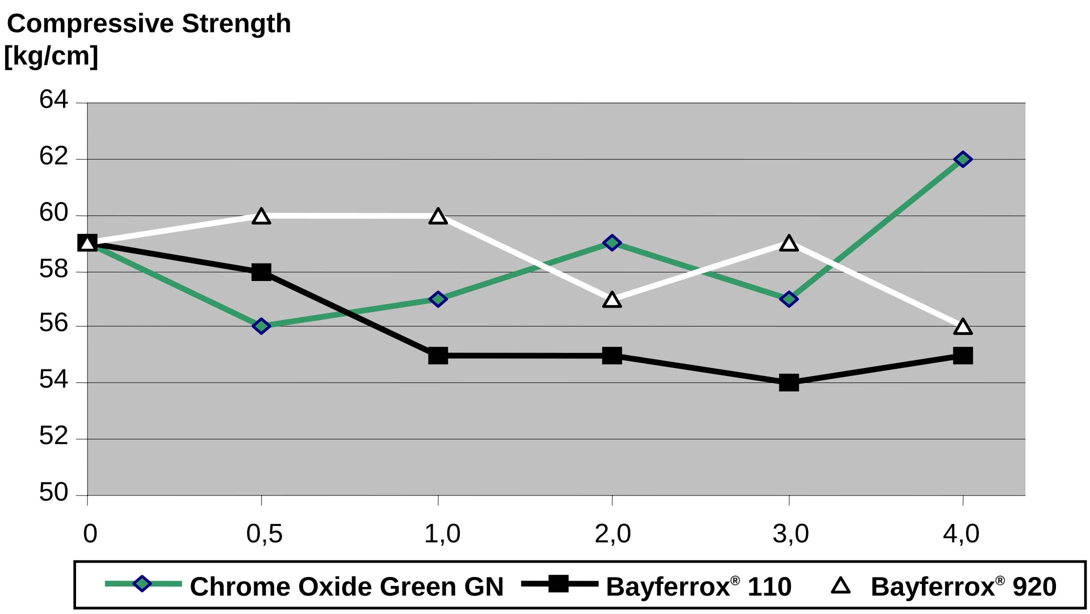

Fig. 2: Bending tension strength of pigmented sand-lime bricks

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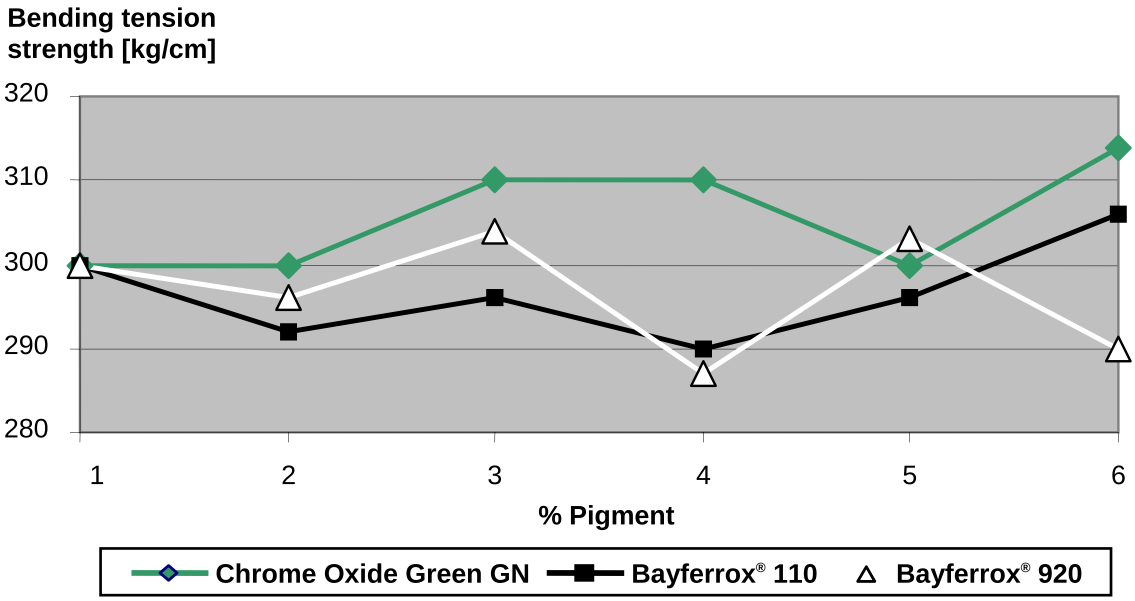

Fig. 3: Compressive strength of pigmented sand-lime bricks

Lightening of sand-lime bricks with titanium dioxide

It is possible to lighten sand-lime bricks by additions of titanium dioxide, as this is already frequently practiced for increasing the wet lightness of white cement. Of the numerous types available on the market, untreated anatase pigments have proved absolutely sufficient for this purpose. Rutiles would have no advantage in this case and are also more expensive. The absolute lightness that can be achieved by an addition of titanium dioxide is, of course, dependent upon the starting lightness of the raw materials used, which in its turn, as has already been mentioned, is above all a function of the natural color of the sand. At any rate even small additions of titanium dioxide permit a distinct lightening, especially when the bricks are wet. Like in the case of the color pigments, higher TiO_2 concentrations do not automatically result in a higher degree of lightness. The economically most favorable range is between 0.5 and 2 % of pigment.

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