The effect of pigments on the quality of concrete blocks

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Introducing pigments

FROM the point of view of concrete technology, pigments are fillers comparable to aggregate fractions passing the No. 350 sieve according to BSS 410. They are very fine particles indeed, and we shall now deal with their properties and their possible influence on concrete.

The tinctorial strength of the pigment largely depends on the fineness of its particles, and therefore in speaking of "good quality pigments" one always means a range of fineness between 2 to 15 m^2/g, and that is an order of magnitude finer than cement. Pigments reflect certain wavelengths of visible light and absorb others and so, according to physical laws, they appear coloured to the human eye. They are also able to maintain these properties in combination with any matter to be coloured, such as for instance cement or lime. Generally speaking pigments can be divided into two large groups: organic pigments and inorganic (or mineral) pigments.

Organic pigments, so called because in the early times of their technology they were derived from animal or vegetable sources in nature and, at the turn of the century, as industrial progress speeded up the development of chemistry, the entire branch of carbon chemistry was called "organic".

Organic pigments possess a very high tinctorial strength and yield the very bright and brilliant colour shades seen everywhere today on automotive finishes, in paints and furthermore in a wide range of applications in the textile, printing inks and plastics industries. Owing to their high tinting strength and very complicated methods of production these organic pigments are rather expensive and, what is of major importance if one is considering the use of these pigments for the colouring of concrete, they have two crucial disadvantages - they cannot be used for the colouring of cementicious materials due to their sensitivity to alkaline reaction, and they are relatively unstable under the influence of outdoor weathering. It is well known that concrete, lime and cement react strongly alkaline and organic pigments will deteriorate (depending on their structure) sooner or later in this aggressive medium.

The second large group of pigments is represented by the so-called mineral or "inorganic" pigments, these being mainly metal oxides of outstanding light fastness and durability. These mineral earth colours are today known as ochres, sienas, or Spanish-, Venetian- or persian-red chemically characterized as iron oxides. They are prepared from mined ore by grinding or calcining, and by washing and subsequent blending of such ores of different composition.

As it is a powder dug from the ground, it is easily understood that fluctuations in composition and varying contents of impurities result in inferior tinctorial strength and colour shades, and this leads to the conclusion that the use of such natural iron oxides as colourants is very often disadvantageous for high standard purposes in the concrete industry. This view together with the continuously rising demand for quality led to the production of synthetic inorganic pigments more than 50 years ago.

Whereas the uniformity of natural mineral pigments depends largely upon the mixed ores receiving the necessary blending operations, to prevent differences in the colour shade, the manufacture of synthetic iron oxides is carefully controlled from the selection of the raw materials down to the finished products. Chemically speaking, synethetic iron oxides are the same compounds as natural oxides but without a greater than marginal content of such undesired matter as water soluble salts, alumina, clay, calcium carbonate and other compounds depending on the deposit of the natural material.

Having characterized pigments as being coloured fillers we must add the term "inert" to emphasize that they take no part in the chemical and physical processes which we call "setting". From this we can draw the conclusion that the influence of pigments can only be expected from the amount of pigment added to the concrete mix, i.e. from the pigment loading.

Pigment loading

If concrete consisting of several components -is to be coloured by means of added pigment, one should know that the colour of every constituent part of the mix affects the final colour of the concrete; and it is easily understood that this effect is less if, at a given colour intensity of the concrete, pigments of higher tinctorial strength are used. Depending on the manufacturing process and the raw materials used, Portland cement can show considerable colour variations, and natural aggregate such as sand and gravel show the same variety. Adding higher loadings of a "poor" pigment might lead to the same colour intensity, but the saturation of shade and colour brightness of "high quality" (synthetic) pigments are mostly unsurpassed.

Increasing the colour intensity can be achieved by adding more pigment up to a threshold value called the Saturation Point, above which an increase in colour intensity will not be noticed. Roughly, if strong synthetic pigments are used, the saturation point for the colouring of block concrete is around *5%* by weight calculated on the weight of dry cement. Slight variations for different colours are possible. The saturation point is also influenced to a certain extent by the grading of the mix, i.e. the more fines (silt beyond 250) in the mix the higher the saturation point. For the best and most economic results, pigment addition should be around the saturation point. It is not necessary to determine this point exactly because, in practice, most pigment addition is carried out to achieve a certain colour shade or according to subjective colour impression.

Water demand

Pigments and other constituents of a concrete block mix have a certain specific surface, and according to physical laws these all have a certain water demand that rises as the specific surfaces increase. This means that adding pigments to a concrete mix might increase the water demand of the concrete in order to maintain a certain workability. Having in mind the saturation point, normally pigment additions do not exceed 5% and within this range an additional water demand will also not be above 5% for most types of pigments suitable for the colouration of concrete block mixes. In general if a steady grading with not too much silt is used for the mix-design, the water demand of the

pigment added does not adversely affect the workability of the fresh concrete.

Water-cement ratio

When adding different amounts of water to a concrete mix (for instance in order to adjust the total moisture content of a block mix to the specific performance of a certain block machine) an alteration of the colour shade will be observed in the finished block. This will be observed no matter whether the concrete has been that has been added, i.e. the higher the water-cement ratio, the lighter will be the colour shade of the pigmented or non-pigmented concrete. The reason for this is simply that the extra water is responsible for a higher moisture content, i.e. the distribution of more cement slurry of lower viscosity throughout the system; surrounding every aggregate particle with more cement slurry. At the same time, of course, higher moisture contents lead to an increase in porosity giving way to more pronounced formation of efflorescence or lime bloom. There is no need to mention that an increase in water-cement ratio lowers the flexural and compressive strengths, and gives rise to more pronounced surface erosion of the block which again affects the original colour shade.

Strength development and pigment addition

As has been mentioned previously, pigments can be considered as "fines" in the aggregate grading. Therefore their influence on the strength properties of a concrete mix can only be judged by two properties; their absolute fineness (specific surface), and as a consequence of this their water demand. Other influences can be safely excluded as pigments are inert as far as the hydratation of cement and cement-aggregate interactions are concerned.

If the strength properties of pigmented concrete are to be tested, this can be done mainly in two ways: by adding pigment (a) at a constant water-cement ratio and (b) at a constant slump.

If a constant water-cement ratio is maintained and pigment is added up to the saturation point or higher, then the strength of the hardened concrete (be it compressive or flexural) measured as usual after 28 days will not be affected negatively as long as the pigment addition is not too far above the saturation point. Only the influences of an additional fines fraction will be noted. The same applies to other concrete properties, such as water tightness, freeze/thaw resistance, shrinkage and creep-behaviour.

Accordingly to the pigments' own water demand, the workability might change somewhat as higher pigment quantities are introduced; this largely depends upon the pigment grade used. In order to overcome this change of workability in the plant or on the site more water might be added to achieve the original workability. This is done in order to work at a constant slump. If concrete mixes with increasing pigment loading are being tested for their strength properties, then decrease in compressive and flexural strength will be noticed if, with higher pigment addition, water had also been added to maintain the original slump. The reason for the decreasing strength, however, is not the addition of the pigment but the addition of the extra water to maintain the original workability. But it is commonly known that increasing the water cement ratio results in a decrease of strength.

No detrimental effects of pigments on concrete will be noticed if the water-cement ratio is kept constant and the pigments can be considered merely as a colourful filler.

Manufacturers of concrete blocks do not have much chance to add pigments to a level much higher than the saturation point as the total moisture content of a concrete block mix is already very low. If too much pigment is used, this might lead to adhesion of the blocks to the ram of the press. This sort of thing will also be noticed if gradings with extreme fines content (approx. *8%* or more on total dry aggregate) are used.

Behaviour of coloured concrete exposed to outdoor weathering

Hardened concrete is extremely resistant to weathering influences but, in the microscopic range, a deterioration of cement occurs at the surface which is responsible for a slight shift in colour that will become noticeable as time goes on.

Depending on the water-cement ratio of the concrete, the cementicious slurry that is always present on a concrete surface because of vibration or other means of compaction will weather off after two or three years, depending on the place of exposure. The colour of the aggregates underneath this surface layer will then be revealed. This results in a colour shift as the colour of the aggregates will be visible together with the cement colour which dominated before the deterioration. If the concrete has been coloured, then this colour shift will go from the coloured cement slurry to a partial aggregate colour. This process can be observed with every type of concrete depending on its mix design and degree of exposure as outdoor weathering proceeds.

In the case of coloured concrete this shift can be more pronounced if the aggregate colour is very much different from the colour of the pigmented cement stone. The degree of this "surface erosion" depends largely on the amount of water that was used in the concrete mix. The more water that was used, the more cement slurry that will cover the concrete surface. The richer the cement slurry, the less resistance it has to wear and tear and outdoor weathering influences, and it will weather off more or less rapidly, thereby revealing aggregates of different colour.

Remarkably, however, once the surface erosion has taken place and an equilibrium between aggregates and cement slurry in the surface has been established, no further colour change will be seen, provided that light and weather stable pigments have been used, and provided that the concrete is not subjected to other influences such as fungus growth or heavy dust deposits.

From this it becomes evident that the selection of aggregates according to their colour might be important for long-term colour consistency in outdoor weathering. Here again a concrete block manufacturer is fortunate in that his mix design has very little moisture and therefore colour shifts due to decomposition of cement slurry can almost be neglected. In the case of concrete block it is more or less mechanical abrasion that might lead to the above mentioned colour shift.

Synthetic iron oxide pigments are of outstanding weathering stability and cement and lime fastness, whereas organic pigments do not meet these basic stability requirements. In this connection it should be mentioned that carbon black, which is often used for the colouring of concrete blocks, cannot be considered to be stable when subjected to long-term outdoor weathering. Although it is not sensitive to the alkaline reaction of concrete, other influences can lead to its deterioration and the reappearance of the original grey.

Modern concrete blocks have an almost unlimited durability - and so has the colour of the block if the necessary care has been taken in selecting suitable pigments.

The use of suitable pigments for colouring concrete paving blocks has opened new and exciting fields of application for this material. The addition of pigments to concrete block mixes can be considered to be of today's technical standard. Whether it be single or random coloured pavement, they both have the same almost unlimited variety for their application and they have long outnumbered clay products.

The facts given in this paper will, 1 hope, help to make coloured concrete paving even more successful.