COLOURING CONCRETE
YESTERDAY'S NIGHTMARE, TODAY'S FUN

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Summary

The paper will describe the state of the art in colouring concrete

(a) by the use of powder material

(b) by the use of aqueous pigment dispersions

The description of these colouring systems also includes a description of the dosing equipment required, the advantages and, in certain cases the disadvantages of the different colouring systems. Special consideration is given to the quality problem inherent in the different colouring systems.

Following the quality assessment of the different concrete colouring systems, the paper presents a concept to simplify the colouring of concrete using pigment granules and a dosing automate. With 3 basic colours - a red, a black and a yellow - it is possible to mix the most important colours. Greens and blues are not considered, due to their high pricing.

The paper further describes the many advantages of such a system :

- very limited stock of four base colours
- marketing freedom in negotiating colours with the architects
- instant realization of customer colour demands.

I introduction

Colouring of concrete has given a new impetus to the use and bright future of this unexcelled construction material in growing markets.

Hand in hand with architects and landscape designers it is the concrete manufacturer who has found new markets by conceiving coloured garden furniture, sound barrier walls, aesthetical flooring, masterpieces of art in facades and functional as well as prestigious roofings.

Coloured concrete is generated by the dispersion of pigments in concrete. "Pigment" stands for the insoluble product that conveys colour to its substrate. Dispersion means the even distribution of the pigment agglomerates or even primary particles throughout the cementitious stone matrix.

Colouring with Powder Pigments

It has been a good tradition to feed the concrete mixer with pigment powder. The advantage of this procedure is self-evident. When you are dealing with 100 % pigment you buy directly from the pigment producer so at first sight it seems to be the most economical solution.

There are some obvious inconveniences when using powder pigment. Firstly depending upon the concrete mixer used and according to mixing intensity, only part of the tinting strength of the pigment powder develops. Modern mixing equipment and long mixing times comprising several minutes, give you a 100 % yield of the tinting strength and of the money you spend for pigments. Ribbon blend mixers and even mixers beyond the state of the present art obviously do not disperse the pigment into its aggregates and primary particles thus up to 30 % of the tinting strength does not develop. Moreover, pigment nests and lumps of undispersed pigment appear frequently as the source of customer complaints. Variation in mixing time brings about variation in colour intensity, producing unevenly coloured concrete products. Last not least, a further quality problem was and is associated with the use of powder pigments due to fault!ve volume dosing and human error.

Liquid Dosage

It has been more than 30 years ago, that Brockhues on the European continent has introduced liquid pigment preparations for use in the concrete industry to overcome the problems of powder dosage. The liquid colours were and are a mixture of the aforementioned powder pigments with water, dispersing agents and stabilizers. The more advantageous liquid pigment preparation resolved the dispersion problem. Intense ball milling of the powder pigments in the liquid state predispersed the pigment into its aggregates and primary particles thus to yield 100 % tinting strength, even in weak concrete mixers. So many of you found in their plants that switching to liquid pigments saved 10, 15 or even 30 % of the pigment due to its predispersion. Volumetric dosage of the pigment was easily done economically and very simply realized in terms of equipment. It complied with the needs of coloured concrete 15 years ago. These readily available dosing units mostly eliminated dust and human error in adding a well defined amount of pigment into the concrete mix.

In using liquid pigments, quality problems were localized in the pigment tank. They are due to varying pigment concentrations, due to pigment deposits after long storage. By using a new pigment container it could happen that in the morning you started with 60 % pigments in your slurry and in the afternoon you were left with 40 % solid contents due to the inhomogenity of the pigment slurry.

Even though the precision of volume dosage was easily realized at a ± 5 % level, variations in the density of the pigment slurries up to 15 % naturally increased the error in pigment dosage, adding up to the error in weighing. Thus it was natural that volumetric pigment dosage in general was substituted by gravimetric pigment metering for higher quality in coloured concrete. Doubtlessly the liquid system and it's easy automation have enhanced the use of colour in many concrete works and has become a widespread technique in colouring concrete.

There are four systematic problems associated with liquid colour :

(a) the colour goes through an additional production process and increases pigment costs;

(b) the water content of the liquid system not always is acceptable especially when using wet aggregates, productivity is lost during the start-up process of the concrete plants;

(c) liquid pigments, I know you don't have the problems over here, do not resist frost;

(d) liquid pigment preparations separate into pigment and water upon storage.

A Granular System for Additive Colour Mixing

By "Additive Mixing" we mean, that you create your own colour on site by mixing different pigments all by yourself.

Additive pigment mixing out of a combination of up to four standard pigments to yield an individual colour is dangerous for the following reasons :

(a) In a customary supplier-pigment user relationship the shades of the pigments vary up to 2 ΔE units, which makes a big difference to the eye;

(b) the tinting strength varies by 100 ±5 % if the pigment used comes from an acknowledged high quality supplier.

In order to further promote quality in coloured concrete, to eliminate the afore mentioned problems and to promote colour flexibility, Brockhues has developped pigment granules together with a dosing system. These granules

- easily di sperse,
- are manipulated very similar to liquid
- don't contain water

and carry a Quality Certificate - which is new to the market place.

This Quality Certificate guarantees especially the "pigment shade" in units of Δ E, a wellacknowledged unit from the paint and varnish industry and - in particular - the tinting strength. This Certificate of Conformity gives the pigment user the guarantee and the possibility of control that the pigment corresponds to what has been agreed upon in negotiations proceeding a delivery. Furthermore, the inclusion of the tinting strength in percent enables the user to correct the required quantity of pigment per mix accordingly and by such to eliminate a 10 % pigment error range in his end product.

Since this Certificate of Conformity accompanies every pigment delivery the tinting strength is known to the end user and is entered into the magnetic memory of the Granumat computer control. By doing so, an error up to 10 % due to the tinting strength differences in usual deliveries from accepted pigment producers, thus is eliminated.

Having the quality of the pigment granules at optimum with the Certificate of Conformity, the problem of additive mixing concentrates now upon errors in weighing different pigments together.

A composite pigment made of three standard colours inevitably will incorporate all dosing mistakes that have been committed during the weighing process of each individual pigment.

This simply means there are two kinds of errors to be taken into account.

(a) Variations in pigment shade and tinting strength as discussed above

and

(b) Variations due to pigment metering.

Problems in Pigment Metering

Granufin accompanied by the Certificate of Conformity being the only pigment to comply with the needs of additive weighing, Granumat seemed to be the most simple metering device to do the job. For this reason the metering tests were made with the Granumat machine.

The precision in metering was tested as follows :

Three different pigments - Granufin Yellow, Red and Black - with three significantly different apparent densities, were chosen.

Granufin was stored in silos above a weigh hopper and metered with a coarse and a fine valve to allow for high precision metering. With our standard equipment, we measured the influence of the apparent Granufin density on metering precision. The metering range was chosen to be 100 g 1,000 g and 10,000 g to allow for the wide range of dosages found in the paving stone industry and to allow for small amounts of pigment to be used in additive colouring. Measurements were repeated ten times to improve statistics and calculate a standard deviation.

Hereby we also tested the influence of the height of the pigment column in the silo above the weigh hopper in order to assess the weighing differences from may be different pigment pressures above the metering valves.

Results

They are found in Table 1.

(1) Test results show that the filling level in the silo above the weigh hopper does not influence metering significantly.

(2) A higher apparent density of the granules did not show a significant influence on the precision in metering even though the pigment column which is still in the air and unweighed when the fine valve closes, has a bigger mass with a higher apparent density.

(3) As we have expected, the differences in g, whether you want to meter 100 g or 10 kg, stay in the same order of magnitude, which is between 10 and 30 g.

This metering mistake is determined by the Granufin mass still in the air when the fine valve closes and therefore is independent upon absolute dosing.

The results in Table 1 gave us a meaningful error estimate for metering, so we now concentrated on colour differences in concrete caused by these potential metering variations. For this purpose we chose six popular composite colours, Antilope, Peat Brown, Caramel, Safari, Sahara and Brick and looked at the colour differences obtained at a 3 % pigment loading in mortar. The contribution of the individual pigments was allowed to vary ± 3 to 5 % in weight, as to allow for potential metering mistakes.

For this purpose mortar samples with a 3 % pigment loading ± the variations were prepared according to DIN No. 53237; the corresponding colour was determined by measuring the samples at ten different spots with a spectrophotometer in order to allow for variances in the mortar surface.

TABLE 1

Granufin	Apparent density g/1		obtained weights and standard deviations at 100 g range weight	standard deviation (g)	1 ,000 g range		10,000 g range	
Yellow	0.62	low fill silo	99	7				
		medium fill silo	99	7	1,003	7	10,000	27
		full silo	100.3	7	1,002	5	9,990	30
Red	1.28	low fill silo	105	12				
		medium fill silo	102	2	1,016	2	9,992	10
		full silo	97	12	1,006	6	10,000	10
Black	1.13	low fill silo	103	12				
		medium fill silo	99	3	987	10	10,001	15
		full silo	98	7	990	6	9,998	11

TABLE 2

Additive Weighing
Influence of Metering Mistakes upon Concrete Colour
for Various Shades

Shade	Composition parts by weight		Metering differences	Δ E max. Δ E average
Antilope	Red	101	± 3 %	.8 (max.)
	Black	40	± 5 %	.5 (average)
	Yellow	159	± 3 %	
Peat Brown	Red	127	± 3 %	.9 (max.)
	Black	131	± 3 %	.4 (average)
	Yellow	46	± 4 %	
Caramel	Red	100	± 3 %	.7 (max.)
	Yellow	200	± 3 %	.4 (average)
Safari	Red	110	± 3 %	.8 (max.)
	Black	45	± 4 %	.5 (average)
	Yellow	145	± 3 %	
Sahara	Red	19	± 10 %	.8 (max.)
	Yellow	281	± 3 %	.4 (average)
Brick	Red	175	± 3 %	.9 (max.)
	Yellow	125	± 3 %	.5 (average)

Results

are presented in Table 2.

Maximum Δ E (CieLab) was found to be .9. These "big" differences occured only when all pigment contributions were maximum above or below the indicated levels. This simply would mean an over- or underdosing by 3 to 5 %. The average Δ E was ca. .5.

The following slides compare the different standard samples and the samples with the biggest differences, due to metering mistakes.

From these findings we judge that maximum metering mistakes in the range of 3 % will bring about an acceptable tolerance in colour variation for coloured concrete, since these will not be noted in a concrete surface.

Looking now at the standard Granumat System and the dosing precision of ± ca.20 g per Granufin applied, we immediately see that the minimum dosing of a pigment by itself or as part of a pigment composition, must not be below 700 g. For example Antilope : here the black pigment is at 40 parts per weight. Since dosing of black must be at least 700 g, the corresponding amount of red will be 1.75 kg and the corresponding amount of yellow will be 2.8 kg; which means the minimal Antilope dosing should be around 6 kg per cement load. Looking at the more critical Sahara, we end up with about a 7 kg pigment load when colouring by additive wei ghi ng.

Thus depending upon pigment composition and colour, the standard Granumat/Granufin System will allow to perform additive weighing from an absolute pigment loading of 3 kg and a minimum pigment contribution of 700 kg onwards. The well defined Granufin quality combined with the Granumat, thus will allow additive colour mixing for most of the commonly found applications for cement loads of about 300 kg per batch and a pigment loading of 3 % and above.

Dealing with the User of White Cement, Smaller Cement Loadings and much Smaller Pigment Loadings

The use of a standard Granumat leads here to unacceptable colour differences. We followed two routes in order to improve the precision of Granumat to 10 and to 5 g. The first measure was to reduce the diameter of the fine dosing valve. By doing so, weight differences were cut down to 10 g. This simply means that the minimum pigment dosage could be lowered to approx. 300 g per pigment contribution without influence upon the colour of the concrete to be coloured.

In a second step by cutting short the distance between the fine valve and the bottom of the weigh hopper, a 4 g precision was reproducibly obtained. With such metering precision a 100 g pigment dosing may become meaningful. At the same time we believe at such small pigment loadings and pigment increments, the weigh hopper has to be redesigned.

We come to the end.

The aforesaid means, that you are able to produce your proprietary colours by colour mixing in a reliable quality, due to

(a) using Granufin, a pigment with a clearly marked tinting strength, and an invisible colour deviation Δ E in shade, guaranteed by a Quality Certificate,

(b) by using the high precision metering system, which is Granumat.

This leads to a number of consequences :

(1) You produce a manyfold range in colours in your products having only 3 to 4 standard pigments in stock. This simply means a decrease in your stock, less storage space and less dead capital bound by now useless pigment stock.

(2) Additive colour mixing with Granufin/Granumat will be a powerful tool for your marketing, because you have the tools to supply new colours to fulfill customer demands overnight; you cut short the six to eight weeks supply time for a special colour from your favoured colour blender.

(3) For marketing again you can offer to the architect and may develop with the architect colours and shades in concrete, that will be successful, because it's not the shade you offer but the shade the market asks for.

Your investment to do so is limited to a scale with a milligram range (analytical balance). Be sure that your pigment supplier teaches you how to do that job.

In summary we showed you a new way how to pave the way to success.

(a) by automation

(b) cutting down on pigment stock through additive weighing

(c) increasing the speed in serving your customer

(d) supplying the tool to do your own colours.

Thank you for your attention.